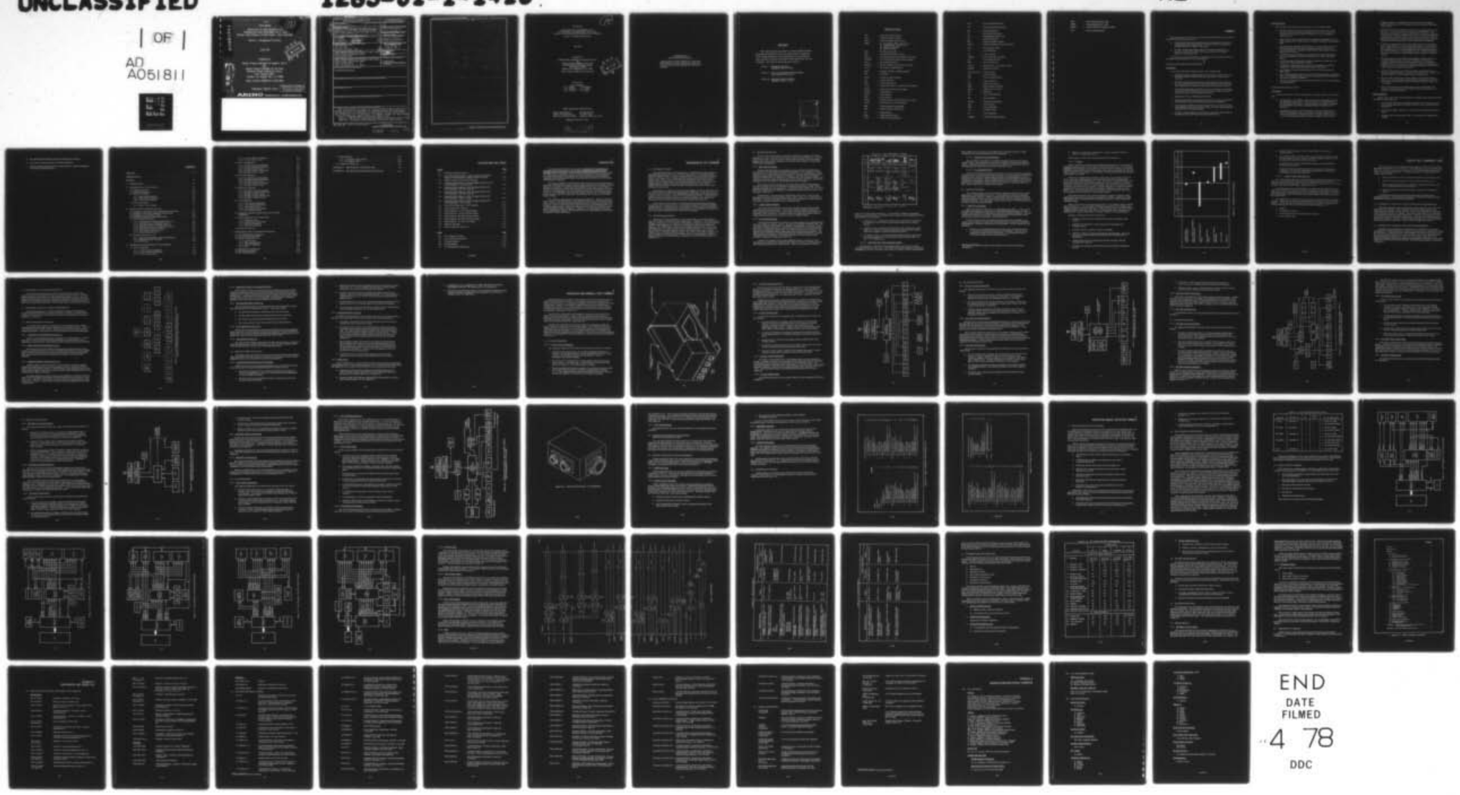
AD-A051 811 ARINC RESEARCH CORP ANNAPOLIS MD F/G 17/7
DEFINITION OF REQUIREMENTS FOR INTEGRATING USER EQUIPMENT SET Z--ETC(U)
JUN 75 B G MCELHANEY, K J BRAMAN F09603-75-A-3001
UNCLASSIFIED 1263-01-1-1413 NL

| OF |
AD
A051811



END
DATE
FILMED
4 78
DDC

Final Report

DEFINITION OF REQUIREMENTS FOR INTEGRATING USER EQUIPMENT SET Z INTO GLOBAL POSITIONING SYSTEM PHASE I TEST AIRCRAFT

Volume I: Management Summary

June 1975

Prepared for

Deputy Program Manager for Logistics (AFLC)
and
Deputy Program Manager for the Navy
NAVSTAR Global Positioning System
Joint Program Office
SAMSO, Los Angeles AFS, CA 90009

Under Contract F09603-75-A-3001-0001

Publication 1263-01-1-1413

ARINC RESEARCH CORPORATION

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (14) 1263-01-1-1413 Vol. I

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER (9)

4. TITLE (and Subtitle) (6)
DEFINITION OF REQUIREMENTS FOR INTEGRATING USER EQUIPMENT SET Z INTO GLOBAL POSITIONING SYSTEM PHASE I TEST AIRCRAFT. Volume I. Management Summary.

5. TYPE OF REPORT & PERIOD COVERED
Final rept.

6. PERFORMING ORG. REPORT NUMBER
1263-01-1-1413

7. AUTHOR(s) (10)
B.G./McElhaney
K.J./Braman
J.N./Schaefer
J.E./Nicholson
~~J.B. Weisel~~
G.R./O'Bryan
~~T.G. Kusik~~

8. CONTRACT OR GRANT NUMBER(s) (15)
F09603-75-A-3001-0001

9. PERFORMING ORGANIZATION NAME AND ADDRESS
ARINC Research Corp.
2551 Riva Road
Annapolis, Maryland 21401

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
(12) 79p.

11. CONTROLLING OFFICE NAME AND ADDRESS
DEPUTY PROGRAM MANAGER FOR LOGISTICS & NAVY (AFLC)
NAVSTAR GLOBAL POSITIONING SYSTEM
JOINT PROGRAM OFFICE

12. REPORT DATE (11)
Jun[redacted]75

13. NUMBER OF PAGES
43

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
DEPUTY PROGRAM MANAGER FOR LOGISTICS & NAVY (AFLC)
NAVSTAR GLOBAL POSITIONING SYSTEM
JOINT PROGRAM OFFICE
SAMSO, Los Angeles AFS, CA 90009

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
UNCLASSIFIED/UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of a study by ARINC Research Corporation to identify and define the requirements for integrating Global Positioning System User Equipment Set Z into specified Air Force and Navy aircraft for GPS Phase I Initial Operational Test and Evaluation. The report is divided into three volumes:

Volume I- Management Summary, publication 1263-01-1-1413
Volume II - Test Aircraft Integration Requirements, publication 1263-01-2-1414
Volume III - Integration Module Definition, publication 1263-01-3-1415

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

400 247

(10)

Final Report

DEFINITION OF REQUIREMENTS FOR INTEGRATING USER EQUIPMENT SET Z INTO GLOBAL POSITIONING SYSTEM PHASE I TEST AIRCRAFT

Volume I: Management Summary

June 1975

Prepared for

Deputy Program Manager for Logistics (AFLC)
and
Deputy Program Manager for the Navy
NAVSTAR Global Positioning System
Joint Program Office
SAMSO, Los Angeles AFS, CA 90009

Under Contract F09603-75-A-3001-0001

Prepared by

B.G. McElhaney
K.J. Braman J.N. Schaefer
J.E. Nicholson J.S. Weisel
G.R. O'Bryan T.G. Kusik

ARINC RESEARCH CORPORATION

SANTA ANA BRANCH
1222 E. Normandy Place
Santa Ana, California 92702

HEADQUARTERS
2551 Riva Road
Annapolis, Maryland 21401

Publication 1263-01-1-1413

ABSTRACT

This report presents the results of a study by ARINC Research Corporation to identify and define the requirements for integrating Global Positioning System User Equipment Set Z into specified Air Force and Navy aircraft for GPS Phase I Initial Operational Test and Evaluation. The report is divided into three volumes:

Volume I – Management Summary, publication 1263-01-1-1413

Volume II – Test Aircraft Integration Requirements, publication 1263-01-2-1414

Volume III – Integration Module Definition, publication 1263-01-3-1415

ABBREVIATIONS

ADF	–	Automatic direction finder
ADI	–	Attitude director indicator
AFCS	–	Automatic flight control system
AIMS	–	A - Air traffic control radar beacon I - Identification, friend or foe M - Military equipment S - Special systems
APU	–	Auxiliary power unit
ASD	–	Aeronautical Systems Division
ASC II	–	American Standards Association Code ASC II
ATCRBS	–	Air Traffic Control Radar Beacon System
ATR	–	Air transport racking
AWADS	–	Adverse Weather Aerial Delivery System
AWLS	–	All Weather Landing System
BDHI	–	Bearing, distance, heading indicator
BW	–	Bandwidth
CADC	–	Central air data computer
CDI	–	Course indicator
CDU	–	Control display unit
COTR	–	Contracting Officer's Technical Representative
DIFAR	–	Directional frequency and ranging
DPGM	–	(Part number)
DPJM	–	(Part number)
DPX	–	(Part number)
DSARC	–	Defense Systems Acquisition Review Council
DT&E	–	Development Test and Evaluation
EMC	–	Electromagnetic compatibility
EMI	–	Electromagnetic interference
FD	–	Flight director
FDS	–	Flight director system
FLIR	–	Forward-looking Infra-red

GPS	–	Global Positioning System
HSI	–	Horizontal situation indicator
IAS	–	Indicated airspeed
IF	–	Intermediate frequency
IFF	–	Identification, friend or foe
IM	–	Integration Module
INS	–	Inertial navigation system
IOT&E	–	Initial Operational Test and Evaluation
JPO	–	Joint Program Office
J/S	–	Jamming/signal
LO	–	Local oscillator
LORAN	–	Long-range aid to navigator
LRU	–	Line replaceable unit
MSU	–	Mode selector unit
OCALC	–	Oklahoma City Air Logistics Center
OMEGA	–	(Navigation system)
PAVE LOW III	–	(Project name)
ppb	–	Parts per billion
PSD	–	Power spectral density
RF	–	Radio frequency
RGA	–	Rotation-go-around
RMI	–	Radio magnetic indicator
RAFB	–	Robins Air Force Base
RS	–	Right side
R/T	–	Receiver/transmitter
SM	–	System Manager
TACAN	–	Tactical air navigation
TAS	–	True airspeed
TBD	–	To be determined
T.O.	–	Technical order
UE	–	User Equipment
VERNAV	–	Vertical navigation system

VOR	–	VHF omni-directional range
VSWR	–	Voltage standing wave ratio
WRALC	–	Warner Robins Air Logistics Center
YPG	–	Yuma Proving Grounds

SUMMARY

The primary goals of the GPS User Equipment Set Z Integration Task conducted by ARINC Research Corporation were:

a. To identify and define the requirements for integrating the Global Positioning System User Equipment Set Z into four Air Force and one Navy aircraft specified for Phase I IOT&E; and

b. To define an Integration Module (IM) for GPS Set Z equipment, as an interface device between Set Z and selected indicators or displays aboard the specified aircraft.

Conclusions and recommendations resulting from work performed toward the two goals of the integration task are presented below.

• UE SET Z INTEGRATION REQUIREMENTS

Conclusions

As a result of the Set Z integration study, it is concluded that:

a. Installation space is adequate in the avionics racks of all five aircraft to mount the GPS Set Z receiver/processor unit when a TACAN set is removed.

b. The Set Z control/display unit can be located in the aircraft cockpit on the center pedestal area for all test aircraft except the KC-135A, where space limitations necessitate an installation at the navigator's station.

c. The antenna/preamplifier assembly can be located on top of the fuselage except on the HH-53 helicopter, where a horizontal stabilizer location may be necessary to prevent pattern anomalies.

d. Installations will use existing aircraft wiring.

e. Antenna/preamplifier temperatures may exceed the design and qualification test limits specified in SS-US-101B for the user equipment.

f. Low frequency vibration of the CDU on the P-3C may exceed the design and qualification test limits of SS-US-101B, the System Segment specification for the User System Segment.

g. All other environmental service conditions specified in SS-US-101B are suitable for Phase I IOT&E on the five aircraft studied.

Recommendations

Based on the Set Z integration study results, it is recommended that:

a. The Set Z receiver/processor be mounted in the avionics racks of the aircraft, replacing a TACAN transmitter/receiver unit in all aircraft except the P-3C, where it should be installed in a space available in cabinet C-1/C-2.

b. The GPS Set Z CDU be mounted on the cockpit center pedestal of all aircraft, except in the KC-135A, where it should be mounted on the navigator's table.

c. The GPS antenna/preamplifier be located on the top fuselage area of all aircraft except the HH-53, where it should be mounted on top of the horizontal stabilizer. Helicopter antenna pattern tests should be accomplished prior to IOT&E.

d. A special mounting be designed in accordance with ARINC Specification 404A to accommodate the receiver/processor unit and the Integration Module.

e. Wiring harnesses be fabricated to enable coupling into altitude and TAS signal wires without destructive splicing.

f. Temperature requirements for the antenna/preamplifier assembly be broadened to match anticipated extreme test environments.

g. Low-frequency vibration specifications for the CDU be increased as design goals.

h. Form, fit and function factors for the Set Z LRU be specified in accordance with ARINC Specification 404A to ensure standardization and compatibility with eventual civilian installations.

i. EMI/EMC considerations be reviewed when the Set Z IF and LO frequencies are being selected.

• INTEGRATION MODULE STUDY

Conclusions

Based on the results of the Integration Module definition study, it is concluded that:

a. The IM can be a very effective interface device for integrating Set Z into the specified test aircraft. The IM will allow for a versatile display of the capabilities of the Global Positioning System when flying a navigation mission with the aid of other instrument displays in addition to the Set Z CDU.

b. Inserting Set Z into the position formerly occupied by a TACAN set is a convenient integration point – interconnection to most flight director systems and displays is readily provided. It might be pointed out, however, that driving just horizontal navigation displays is only half the

navigation solution. Interfacing Set Z also with vertical navigation displays would provide for a demonstration of the complete GPS navigational situation.

c. The IM described and specified in Volume III is a simple signal converting device. It does not perform any data processing functions, but instead relies upon Set Z software to perform these routines. However, it does have the ability to transform Set Z from an isolated and independent navigation system into part of the integrated avionics suite with the capability of displaying a highly accurate navigation solution on the pilot's primary flight instruments, and in terms with which he is familiar.

d. If Set Z is to supply the dc power for the IM, then the size of the Set Z power supply will have to be increased significantly to accommodate the power requirements for the IM configuration described in this report. This situation can lead to both packaging and heat dissipation problems for the Set Z contractor. Incorporating the power supply in the IM would allow that device to operate independently of Set Z except for interface signals.

e. The input signals from the IM to Set Z (magnetic heading, course set, and true airspeed) require special Set Z software processing not originally specified in the user system specification. The magnetic heading and course set signals are required for IM reference purposes to ensure correct placement at the instrument indicators, while the TAS signal eliminates a manual input function.

f. A built-in-test feature for the IM also requires special software routines not originally specified. However, these routines are minimal and should not add much to the existing software requirements.

g. Set Z presents a slight impact on the design of the IM in the interface signal area. At this time the signal structure and format have not been determined; this information is needed so that the IM input circuits can be specified.

h. None of the impact areas described appear to be overwhelming, and should be resolvable through a joint effort of the Set Z contractor, the GPS JPO, and the IM designer.

Recommendations

Based on the results of the Integration Module definition study, ARINC Research Corporation recommends that:

a. One of the IM configuration alternatives offered in this report be selected as the desired approach to an effective interface device, preferably configuration D.

b. The exact load (HSIs, BDHIs, etc.) to be driven by the IM be specified in detail.

c. A definite Set Z-to-IM interface digital code structure be identified and defined.

d. The preferred IM mounting location be identified and specified.

e. The source of IM dc power (Set Z or IM) be identified.

f. Further study be performed on the requirements for using and integrating the vertical navigation function.

CONTENTS

ILLUSTRATIONS AND TABLES

1
INTRODUCTION

This first part of the three-volume report, Definition of Requirements for Integrating User Equipment Set Z into Global Positioning System Phase I Test Aircraft, presents a summary of the detailed information contained in Volumes II and III. This volume is intended to provide a concise description of the background for and significant findings of the program, the scope of work performed during this integration effort, and appendix listings of government/industrial source documents and individuals contacted.

The contract (F09603-75-A-3001-0001) under which this work was performed is part of the GPS Integrated Logistics Support Program directed by GPS Deputy Program Manager for Logistics. The study produced information that will not only help the GPS JPO prepare for the IOT&E effort during Phase I of the GPS program, but which will also be of significance to the user equipment manufacturer during the design of UE Set Z. This information will primarily influence the form, fit, and (where appropriate) function of the Set Z equipment to be integrated into the five test aircraft for Phase I IOT&E.

This volume is divided into five sections plus appendixes. Section 2 presents a brief overview of the GPS program, with emphasis on the areas most relevant to this study. Section 3 discusses the tasks performed under the contract and how they were organized. Section 4 summarizes the material in Volume II concerning the Set Z-to-aircraft integration study. Section 5 summarizes the material in Volume III concerning the Integration Module investigation. Appendix A is a bibliography of the documents supporting the analyses, and Appendix B lists the organizations and individuals contacted for further information.

2
BACKGROUND OF GPS PROGRAM

2.1 PROGRAM OVERVIEW

The NAVSTAR Global Positioning System is a satellite-based radio navigation and positioning system that will evolve from a three-phase development program: concept validation (Phase I), system validation (Phase II), and production (Phase III). Objectives of Phase I are to validate the GPS concept, identify the preferred GPS design, define system costs, and demonstrate the military value of the system. Phase I will be completed by the end of the first quarter of 1978, at which time the second program meeting of the Defense Systems Acquisition Review Council (DSARC II) will determine whether the Phase I objectives have been met and if the program should proceed.

During Phase II, which commences after the DSARC II decision, the system will be validated and its operability and supportability established. By the conclusion of Phase II, at the end of 1981, a two-dimensional (latitude/longitude) limited operational capability will be available worldwide to all suitably equipped users. After Phase II has been completed, DSARC III will be convened to determine if the objectives of Phase II have been met and whether the program should enter Phase III.

Phase III of the GPS program will build upon the two-dimensional capability developed in Phase II and proceed to a global three-dimensional navigation capability (adding altitude). During this phase, user equipment will be procured in production lots as determined by individual user requirements. By the completion of Phase III in 1987, the Global Positioning System will be fully operational.

2.2 PROGRAM MANAGEMENT

Management of the GPS program is the responsibility of the Joint Program Office of the Space and Missile System Organization, Los Angeles. The GPS Program Manager, through his service/agency deputy program managers, and supported by the Deputy Program Manager for Logistics, coordinates and directs the overall GPS program. The DPML serves as the prime coordinator and advisor to the JPO Program Manager on all logistics aspects of the system acquisition. He is responsible for the total DoD integrated logistics functions for the Air Force, Navy, Army, Marine Corps, and Defense Mapping Agency. The office of the DPML coordinates all service logistics requirements, draws up the plans for implementation, designs a program that ensures implementation, and prepares for the GPS test program (see Section 2.4.1).

2.3 SYSTEM DESCRIPTION

The GPS will provide highly accurate three-dimensional position and velocity information as well as system time to suitably equipped users anywhere on or near the surface of the earth. The GPS consists of three major elements: the Space System Segment, the Control System Segment, and the User System Segment, as described in the following paragraphs.

2.3.1 Space System Segment

The Space System Segment will comprise a fully operational configuration of 24 satellites, six of which will be launched during Phase I. The satellites, or space vehicles, will be evenly deployed in three 10,000 nm circular, subsynchronous orbits 120 degrees apart with an inclination of 63 degrees. Each satellite will transmit a signal at 1575 MHz that is a composite of a protected and clear navigation signal. The composite signal will contain navigation data such as satellite ephemeris, atmospheric propagation correction factors, and satellite clock-bias information.

The satellites will also transmit a second navigation signal at approximately 1227 MHz to permit the user to determine ionospheric group delay or other electromagnetic disturbances in the atmosphere. All the transmitted signals will be received by the User System Segment equipment and automatically processed into a form comprehensive to the user.

During Phase I, the six-satellite configuration will provide a "four-in-view" geometry for periods of GPS navigation of up to 3 hours a day over selected areas of the CONUS. The fully operational system will provide continuous coverage for three-dimension navigation and positioning on a worldwide basis.

2.3.2 Control System Segment

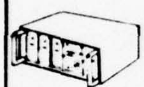
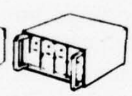
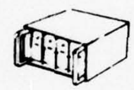
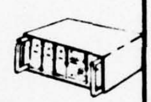
The Control System Segment will track the satellites and determine satellite ephemerides and system time bias. Four widely separated monitor stations will gather information for the master control station to use in orbital determination and systematic error elimination. An upload station will supply the satellites with the update information they need to generate accurate navigation signals.

2.3.3 User System Segment

The User System Segment will include all of the necessary user equipment hardware and software to receive, process, and display the satellite navigation data. The basic user equipment will consist of an antenna, a preamplifier, a receiver, a data processor, a control/display unit, and the required software to control the hardware. When receiving navigation signals from each of the four satellites, the receiver will measure four independent pseudo-ranges and pseudo-rates from the satellites. The data processor will then convert these data into three-dimensional position, velocity, and system time information. The position solution will be developed in earth-centered coordinates and displayed on the CDU.

During GPS conceptual and program definition studies, six classes of user equipment were identified and defined by the military services as necessary to meet their operational performance requirements. Table 2-1 summarizes the defined

TABLE 2-1. USER EQUIPMENT CLASSES

	A	B	C	D	E	F
BY CLASS						
BY FUNCTION	High Accuracy[1] Medium dynamics of user High immunity to jamming	High accuracy[1] High dynamics o' user Medium immunity to jamming	Medium accuracy[2] Medium dynamics of user Immunity to unintentional EMI Low cost	High accuracy Low dynamics of user High immunity to jamming	High accuracy Low dynamics of user High immunity to jamming Low weight Low power	High accuracy Fast acquisition Low dynamics
BY POTENTIAL APPLICATION[3]	AIR FORCE Strategic aircraft Photo reconnaissance	ARMY Helicopter USMC Close air support Helicopter NAVY Close air support Surface vessels Attack aircraft AIR FORCE Interdiction Close air support	ARMY Mission support NAVY Mission support Surface vessels ASW aircraft AIR FORCE Airlift Search & Rescue Mission support	ARMY Wheeled and tracked land vehicle NAVY Mine warfare Surface vessels Surface ships 40 kts	ARMY Man backpack USMC Man backpack	NAVY Submarine
BY EQUIPMENT						

[1]High Accuracy = Better than 50 ft; [2]Medium Accuracy = 50–500 ft;
[3]Acceptable Accuracy for Cost

levels of user equipment performance. To meet Phase I budgetary constraints, however, it was necessary to consolidate the six classes of user equipment into three representative receiver types:

a. A high-accuracy, continuous tracking receiver (X) having a minimum of four channels, each dedicated to processing signals from a specific satellite.

b. A high-accuracy, sequential tracking receiver (Y), having one or more channels and capable of sequencing through satellite-generated signals rather than continuous tracking by individual channels.

c. A medium-accuracy, low-cost sequential tracking receiver (Z), having one channel capable of receiving only the clear navigation signal in a sequential tracking mode.

2.3.3.1 Generalized Development Models X and Y

During Phase I, generalized development models of Sets X and Y will be developed, fabricated, and tested. Each GDM will have the capability of functionally simulating several user equipment classes that will satisfy a variety of applications.

These GDMs will be test beds for investigating and evaluating alternative design concepts for increased sophistication of user equipment.

2.3.3.2 Advanced Development Models

Upon selection of candidate user equipment design concepts early in Phase I, UE Sets X and Y will be developed to the level of maturity of advanced development models. Sufficient quantities will be procured to support a comprehensive test and evaluation program from which a preferred design will evolve.

2.3.3.3 User Equipment Set Z

Concurrent with the development of the UE Sets X and Y, Set Z will be designed and fabricated as an engineering development model. In the development of that model, emphasis will be placed on obtaining high reliability and maintainability at low cost through the use of common, modular components and by incorporating a high degree of subassembly commonality. Major attributes of Set Z are its relatively low cost, high potential for reliability, and applicability to the largest user population segment in DoD. Set Z is the model of concern in this report.

2.4 GPS TEST PROGRAM

The GPS test program will be conducted in compliance with AFR 80-14, AFSC Supplement I, and DoD Directive 5000.3.* The program will include Development Test and Evaluation (DT&E), Follow-on Development Test and Evaluation (FODT&E), Initial Operational Test and Evaluation (IOT&E), and Follow-on Operational Test and Evaluation (FOT&E). The relationship of these tests to Phase I of the GPS program is discussed in the following paragraphs.

2.4.1 Phase I Test Program

Most of the DT&E for GPS will be accomplished during Phase I. DT&E will be conducted by the equipment contractors to refine engineering and design, measure progress, and verify the accomplishment of system development objectives. The data resulting from DT&E will be used to verify the performance characteristics of the system and to determine compliance with specifications.

OT&E will focus on the development of operational tactics, techniques, procedures, and concepts for systems and equipments; and the evaluation of reliability, maintainability, operational effectiveness, and suitability. OT&E is divided into two categories:

a. IOT&E, to be accomplished prior to the first major production decision to determine operational effectiveness and suitability. Only Set Z user equipment will enter IOT&E during Phase I. This integration study is concerned with that phase of the test program.

*All documents denoted by number in this report are more fully referenced in Appendix A.

b. FOT&E is accomplished subsequent to receipt of production items; no FOT&E is schedule for Phase I.

The remainder of this section will discuss the IOT&E program.

2.4.1.1 IOT&E

Phase I and Phase II IOT&E for the NAVSTAR GPS program will be directed at obtaining evaluations of the military utility, operational effectiveness, and operational suitability of the prototype user equipment sets and the Control Segment. Operational suitability evaluation will include assessments of the logistics supportability, life cycle costs, reliability, maintainability, survivability, training requirements, and desirable modifications or tradeoffs.

IOT&E will be conducted by personnel of the Army, Navy, Marine Corps, Air Force, and Defense Mapping Agency having the same specialties and experience levels as the planned operational users. Tests of Set Z will be conducted under conditions that simulate actual operational situations as closely as possible, but within areas where acceptable satellite viewing geometry exists and where adequate position verification measurement is practicable. It will be desirable to conduct most IOT&E using the optimum six-satellite initial development configuration; however, some IOT&E (e.g., operational suitability testing and pre-IOT&E rehearsal) may be conducted using the Inverted Range at Yuma Proving Grounds.

Appropriate data from DT&E will be used where possible in IOT&E to reduce testing costs and to preclude redundant or unnecessary testing. Additionally, flight test missions will be coordinated and consolidated among the services to preclude redundant testing.

Phase I IOT&E will be conducted only for Set Z, in accordance with the schedule shown in Figure 2-1. As much useful information as possible will be sought in support of test objectives prior to DSARC II. Phase II IOT&E of Set Z will be directed at verifying tentative conclusions from Phase I, refining performance estimates, and obtaining more complete information on costing, reliability, and maintainability.

Objectives of Phase I/II IOT&E of GPS are to:

a. Establish a firm life-cycle cost data base for the GPS design-to-cost process.

b. Evaluate GPS capability to support general user positioning and navigation needs.

c. Evaluate common-coordinate reference capability.

d. Determine ability to perform photomapping, phototargeting, and search and rescue missions without the need for ground reference points or benchmarks.

e. Evaluate improvement in capability to perform airborne refueling operations by using GPS.

f. Evaluate area navigation and terminal approach navigation capabilities of GPS.

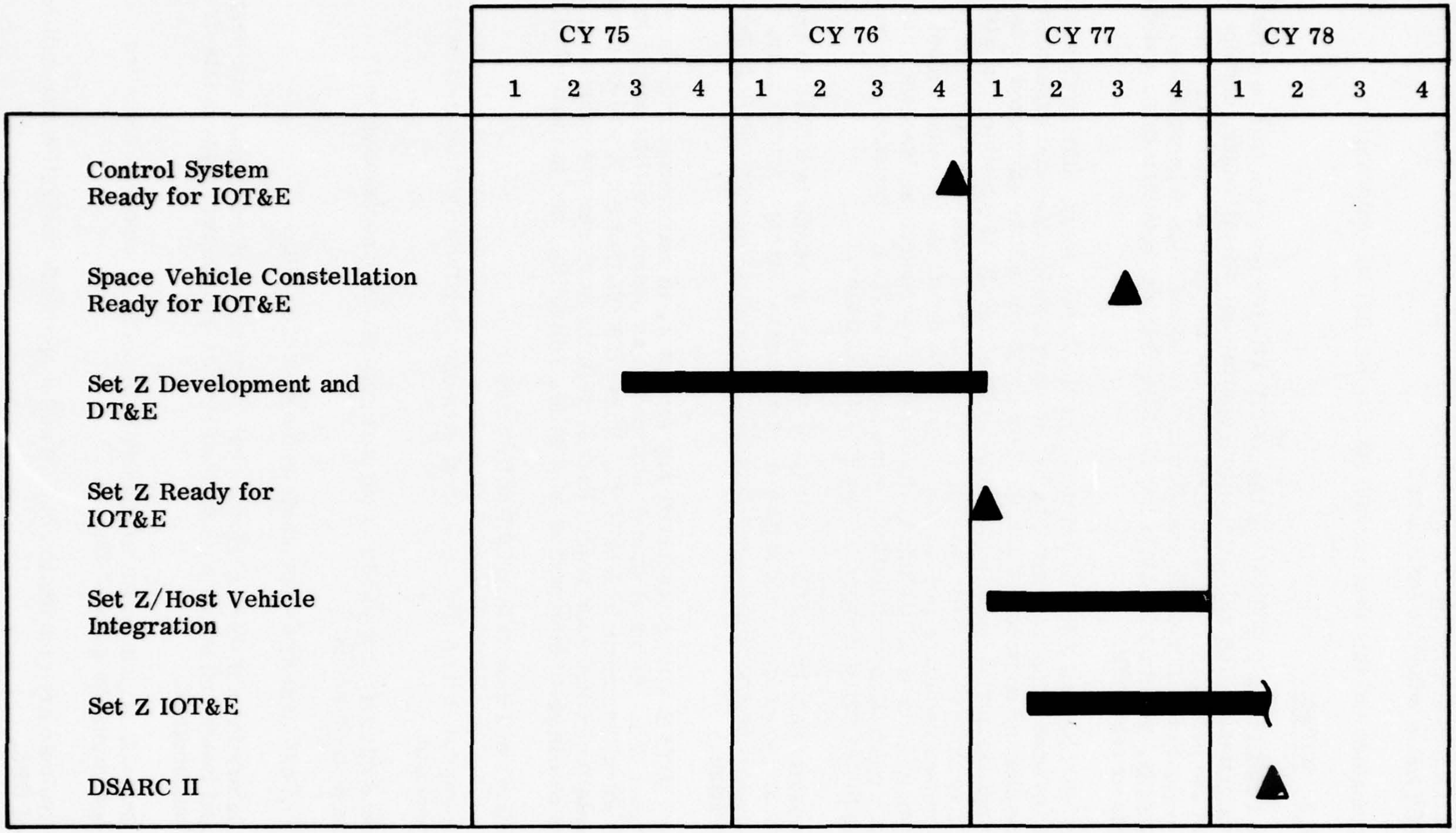


Figure 2-1. GPS Phase I IOT&E Schedule

g. Perform initial evaluation of system vulnerability to jamming and unintentional RFI.

h. Evaluate the military potential of the user terminals for airborne, ground and sea employment (e.g., nap-of-the-earth, intelligence gathering, target acquisition, and ground vehicle operations).

i. Evaluate the value of three-dimensional position and velocity information to military systems.

j. Evaluate operational suitability to include assessments of logistics supportability, life cycle cost, reliability, maintainability, survivability, vulnerability, and training requirements.

2.4.1.2 Logistics Support During IOT&E

One of the primary objectives of the ILS program during the GPS Phase I IOT&E effort is to ensure the effective integration and installation of Set Z into the test vehicles associated with this study. These test vehicles include the Air Force C-141A, KC-135A, HC-130H, and HH-53B/C; and the Navy P-3C.

The installation will be accomplished in accordance with the applicable service regulations, and will be developed as close to an operational configuration as possible. Test vehicles will be returned to their normal configuration after testing. No structural modification or other modification that degrades operational safety will be made to any test vehicle.

The equipment to be installed in the test aircraft consists of both Group A and B items. Group A items include all interconnecting and interfacing wiring, mounting adapters, the IM, and other miscellaneous hardware necessary for installing Set Z into the test aircraft. Group B items include all Set Z equipment, i.e.:

a. Antenna

b. Preamplifier assembly

c. Receiver/processor unit (including power supply)

d. Control/display unit

3
SCOPE OF SET Z INTEGRATION TASK

The scope of the GPS User Equipment Set Z integration study is to provide Set Z integration information to the GPS JPO in a sufficiently timely manner to influence the form, fit, and where appropriate, the function of the equipment being designed by the Phase I user equipment contractor. The tasks necessary to accomplish this study consist of the following:

a. Define the individual vehicle integration requirements and problem areas.

b. Define the composite integration requirements and problem areas.

c. Define an Integration Module and identify the appropriate interfaces with aircraft onboard displays and instruments.

d. Define requirements for special testing to verify that the integration is effective.

The following discussion describes these tasks and the methods used in accomplishing them. Also discussed are directives received from SAMSO JPO that impacted on these tasks during their performance.

3.1 DEFINITION OF INDIVIDUAL VEHICLE INTEGRATION REQUIREMENTS

Individual integration requirements for Set Z were defined for each of the five IOT&E test aircraft types. These requirements included defining the interface between the Set Z and the aircraft avionics, as well as the environment in which the vehicle (and hence Set Z) is to operate. The product of this effort was a comprehensive integration checklist for each aircraft type. Particular consideration was given to possible unusual environmental conditions, power inadequacies, electromagnetic interference problems, potential antenna location problems, form and fit constraints, and control/display requirements. Details of this task appear in Volume II.

3.2 DEFINITION OF COMPOSITE INTEGRATION REQUIREMENTS

Individual aircraft integration requirements were combined into composite, comprehensive requirements that will support the development of a single Set Z design for GPS Phase I. During this effort, special attention was given to the Group A items that could be designed uniquely for a given aircraft so as to avoid a costly common design compatible among all the aircraft. The final product of this task was a composite integration specification defining the integration requirements for the installation of Set Z into the IOT&E test aircraft. That specification appears as Appendix A of Volume II.

3.3 DEFINITION OF AN INTEGRATION MODULE

The integration requirements for Set Z to interface effectively with other avionic systems and instruments onboard the test aircraft were studied. From this study an approach to the design of a common Integration Module evolved. The performance characteristics and system integration requirements for the IM were transformed into a specification that followed the format suggested in MIL-STD-490 for a form, fit, and function specification. Details of this task are presented in Volume III.

3.4 DEFINITION OF SPECIAL TESTING REQUIREMENTS

Special testing required to verify the integration requirements identified by the above definition studies are described in Volume II, Section 8. Detailed in that section are the special tests required for individual aircraft integration, composite integration, and the IM.

3.5 WORK BREAKDOWN STRUCTURE

To systematically organize and manage the overall integration task, ARINC Research prepared and implemented a detailed work breakdown structure. Figure 3-1 is the WBS developed for this contract, showing each of the major study tasks and constituent subtasks. These tasks are briefly described in the following paragraphs.

3.5.1 Integration Task Administration (Task 1.0)

General project administration was performed on a continuing basis. The primary areas covered by this task included identifying and solving problem areas, maintaining customer liaison, and preparing informal engineering working documents.

3.5.2 Data Collection and Handling (Task 2.0)

The primary sources from which the background and supporting data for this contract was gathered included GPS user equipment documentation, aircraft technical orders, avionic technical orders, equipment specifications, aircraft environmental data, and personal contact with GPS contractor personnel and aircraft system managers.

3.5.3 Integration Module Definition (Task 3.0)

Defining an IM to perform the Set Z-to-aircraft avionics interface required studying and analyzing each test aircraft navigation system to determine the likely avionic suites with which to interface. Block diagrams of the integration of Set Z into each aircraft navigation system were prepared, and the signal characteristics for each of the interface signals were listed.

One design approach to an IM was taken and investigated to determine the feasibility of the performance requirements of the specification to be prepared as a result of this task. A hardware cost analysis was made of this approach along with a power consumption analysis. A brief review of possible alternate configurations for an IM was also made.

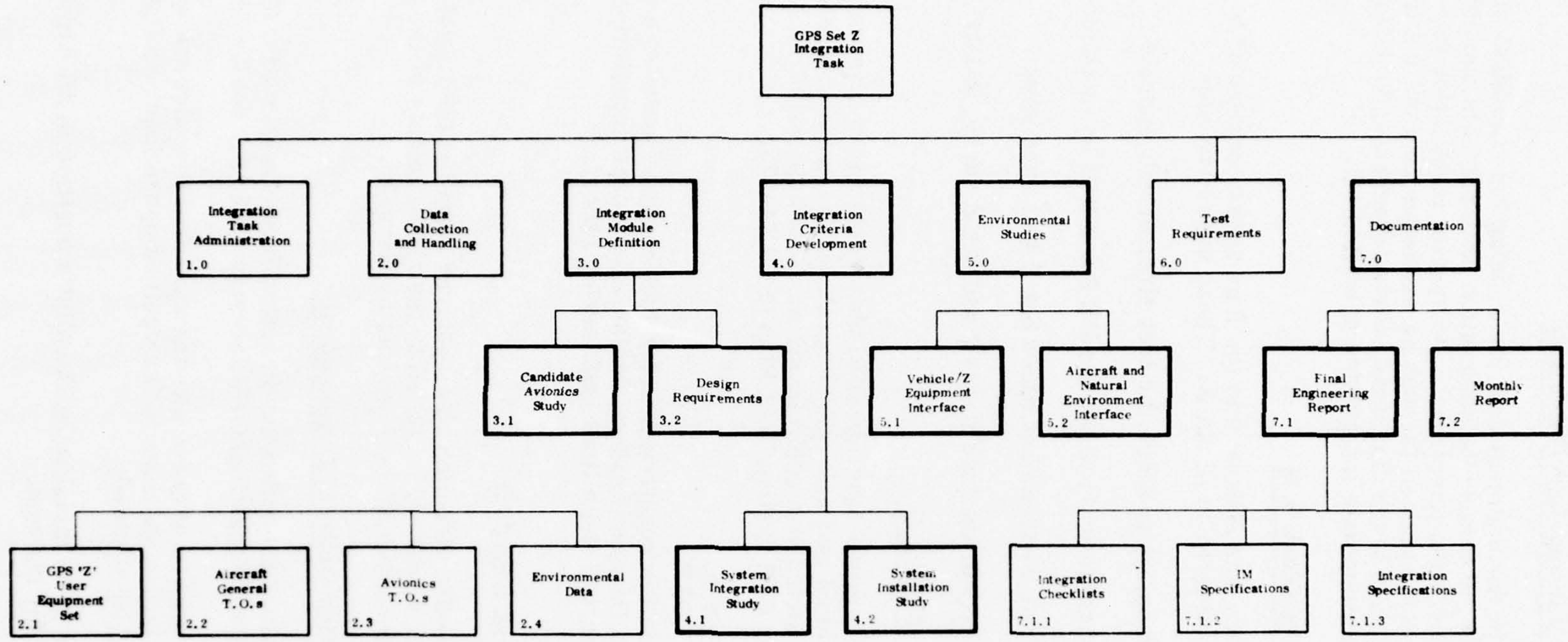


Figure 3-1. Work Breakdown Structure, ARINC Research Corporation Support to GPS Integrated Logistics Support Program

3.5.4 Integration Criteria Development (Task 4.0)

The integration criteria development task for defining the individual aircraft integration requirements and the composite integration requirements consisted of studying both the system integration (electrical) and system installation (mechanical) requirements. Information was obtained through an extensive data collection effort and analyzed to develop interface block diagrams, wiring diagrams, installation diagrams, checklists, and a composite integration specification.

3.5.5 Environmental Studies (Task 5.0)

The environmental study was divided into the four areas considered to be the most important to effective integration of Set Z. These areas include:

a. The natural environment in which the test aircraft will operate

b. Potential EMI environment in which the UE Set Z will be installed

c. The internal aircraft environment which Set Z will encounter

d. The exposure history of the test aircraft and Set Z during IOT&E.

3.5.6 Test Requirements (Task 6.0)

The special test requirements task included identifying any special integration tasks required for the individual test aircraft integration, the composite integration, and the IM. This task also included specifying any modifications required to the GPS Master Test Plan and/or the GPS System Test Plan (YEN 74-273).

3.5.7 Documentation (Task 7.0)

The specific documentation requirements for this contract included a composite integration specification, an IM specification, individual aircraft integration checklists, monthly progress reports, and a final engineering report.

3.6 DIRECTION FROM THE GPS JPO

During this study, specific direction was received from the GPS Joint Program Office that further clarified, modified, or added to the requirements of the contract. Significant directives are discussed in the following paragraphs.

3.6.1 Integration/Installation Criteria Development

ARINC Research received the following direction from the GPS JPO COTR on the development of the system integration/installation criteria for Set Z:

a. The physical integration of Set Z into the specified test aircraft will be aimed at an installation as close to the desired operational configuration as can reasonably be attained.

b. The Set Z CDU is to be installed at the pilot's position in all Air Force aircraft selected for the test.

c. Maximum use will be made of existing aircraft system avionics, wiring, connectors, etc. The use of special junction boxes, selector panels, wiring, etc., will be avoided to the extent practicable.

d. The Set Z receiver/processor will physically replace one of the two existing TACAN sets in the selected test aircraft. If the test aircraft is equipped with only one TACAN set, then Set Z receiver/processor will replace the set.

e. The selection of the CDU-to-Set Z receiver/processor connectors will be based on current TACAN control panel wiring to the extent possible.

f. The TACAN set on the P-3C will remain in place and Set Z will share the TACAN displays through the use of a relay junction box.

3.6.2 Integration Module Definition

In addition to the applicable criteria for Set Z (see above), the following direction was received from the COTR on the definition of an Integration Module:

a. The output of the IM will drive the same displays as now driven by the TACAN set on the selected test aircraft.

b. The IM will be developed to drive horizontal type display such as the horizontal situation indicator and bearing distance and heading indicator only. The radio magnetic indicator and the course deviation indicator will be driven if the HSI or BDHI selection is not appropriate. Driving any of the aforementioned indicators will provide the pilot with a continuous display of the horizontal navigation situation being computed within Set Z.

c. The mechanical design requirements of the IM will be specified such that the module will be circuit card or cards that plug into the Set Z receiver/processor. However, if further study of IM output requirements determines that this situation is not practical or possible, then the IM will be specified as a separate unit to be mounted as close as possible to the receiver/processor.

d. The IM will receive encoded altitude and true airspeed from the appropriate aircraft systems and condition them for use by Set Z.

3.6.3 Other Areas

Further direction was received from the COTR to prepare informal engineering working documents on various subjects relating to the work performed for the contract. The significant areas in which this direction was received include the following:

a. Prepare a list of the avionic systems to be interfaced with Set Z for each of the test aircraft, based on the study and analysis of these systems prior to 15 January 1975 (Vol. III, Section 2).

b. Prepare a paper describing the mechanization and rationale of the cross-track deviation signal (Vol. III, Appendix C).

c. Investigate the use and application of ARINC Specification 419 to the development of the Set Z IM interface (Vol. III, Appendix E).

d. Recommend the appropriate values of course deviation sensitivity for the enroute, terminal, and approach modes of flight for use by the Set Z contractor (Vol. III, Appendix D).

4
INTEGRATION REQUIREMENTS STUDY SUMMARY

Set Z integration requirements were defined for five types of aircraft selected by the GPS JPO for Phase I IOT&E. These requirements were premised on the physical replacement by, or compatible installation of, Set Z for a TACAN set in each aircraft type. Interfaces with existing cockpit instruments were limited to those relating to the TACAN, i.e., bearing, distance, course deviation, and flag signals. A common mounting was defined to accept the receiver/processor unit and the Integration Module elements; see Figure 4-1.

The Set Z CDU was located in the cockpit, except in the case of the KC-135, which could not accommodate it. Where possible, existing aircraft wiring was utilized to connect Set Z, but such wiring was kept intact to permit easy reversion to the original aircraft configuration. No special cooling facilities for the Set Z equipment were considered necessary on these aircraft.

Results of the integration study for the specific aircraft types selected for Phase I testing are discussed in the following section. In all instances, Set Z integration data were derived from a review of aircraft technical orders and manuals, discussion with aircraft technical services/engineering personnel at WRALC, and inputs from aircraft manufacturer representatives. Complete test aircraft integration details for incorporating the GPS Set Z equipment in these aircraft types may be found *in Volume II.*

4.1 C-141A INTEGRATION

4.1.1 C-141A Group B Installation

The suggested installation of the LRUs of Set Z into the C-141A is as follows:

a. The Set Z receiver/processor, in a common mounting with the IM, is located in the left hand underdeck avionics equipment rack of the C-141A aircraft. The equipment replaces the TACAN No. 1 receiver-transmitter unit and its mounting.

b. The Set Z CDU is mounted in the C-141A cockpit on the left side of the center console. The TACAN No. 1 control panel is removed and other panels rearranged to make sufficient space available.

c. The Set Z antenna/preamplifier assembly is located on top of the aircraft at the center wing area where it replaces the top antenna of TACAN No. 2. The compartment into which the preamplifier extends is unpressurized and unheated; see Section 4.1.4 for further discussion.

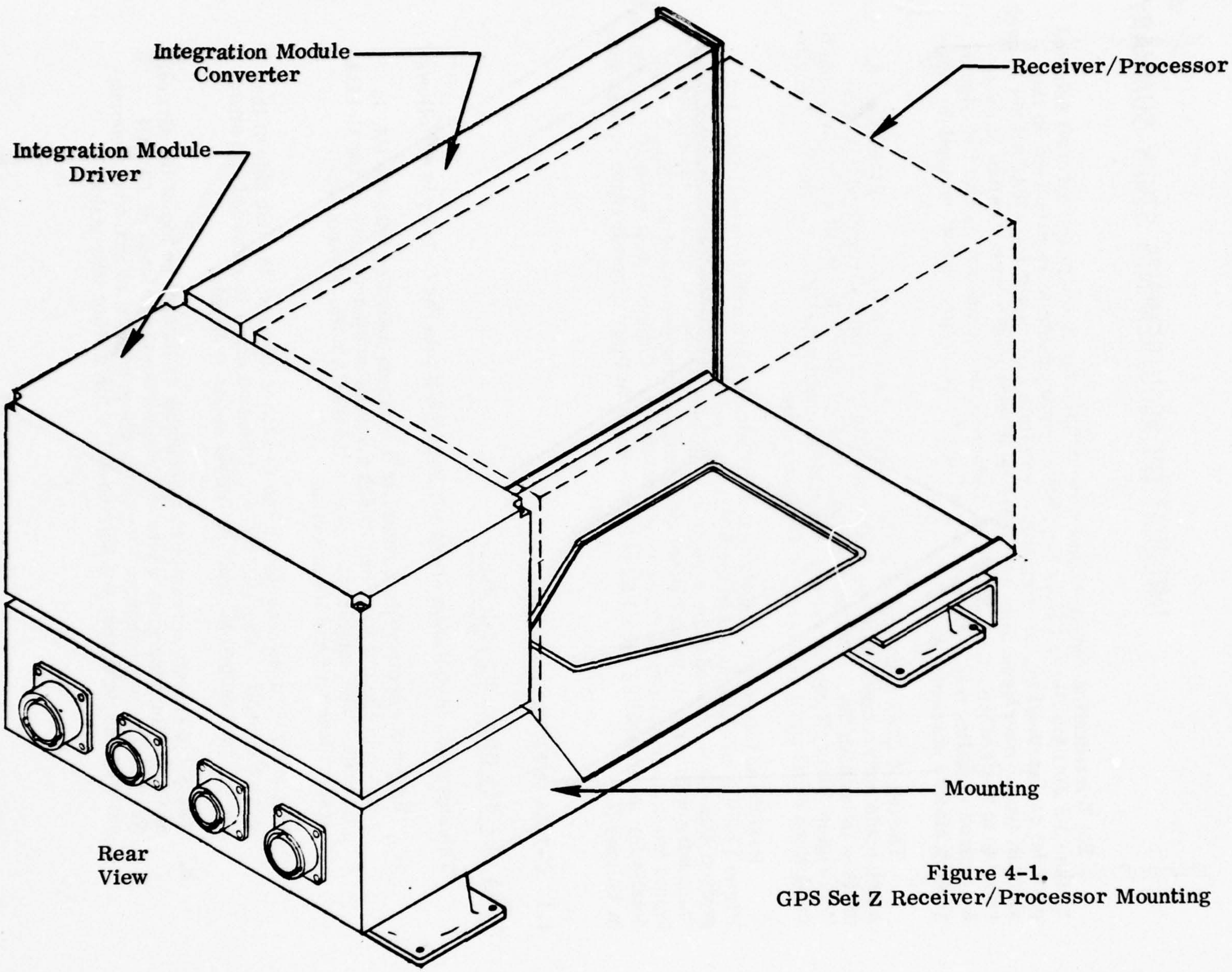


Figure 4-1.
GPS Set Z Receiver/Processor Mounting

4.1.2 C-141A Functional Interfaces

The Set Z receiver/processor and IM will connect to the C-141 aircraft flight director and navigation instruments via existing TACAN No. 1 wiring through the navigation junction box, as shown in the simplified block diagram of Figure 4-2. For navigation data selection, Set Z will replace the TACAN No. 1. The CDU connections will use the existing TACAN No. 1 wiring between the avionics equipment rack and the cockpit center console.

TAS and altitude data will be input into the Set Z via special wiring harnesses, which couple into aircraft circuitry without damage or modification to existing wiring. Semiflexible foam-dielectric coaxial cable will be installed between the avionics equipment rack and the pressure bulkhead at the fuselage overhead (near the wing leading edge) to connect receiver/processor and antenna/preamplifier. A spare caution panel light in the cockpit may be connected for GPS degraded-mode alert.

4.1.3 C-141A Group A Items

Group A items required for the indicated Set Z installation in the C-141A aircraft include:

a. A receiver/processor mounting, which incorporates rack-and-panel connectors for plug-in connection of the receiver/processor and IM elements, platform vibration isolators, type C holddowns, and ARINC-type cooling orifices. External connections for interface wiring utilize MIL-C-83723 circular connectors at the rear of the mounting.

b. An antenna/preamplifier mounting, consisting of the structural doubler and mounting hardware to be specified during the installation engineering phase.

c. An IM converter, which provides digital-analog interfacing with other aircraft systems.

d. An IM driver, which supplies the low-impedance analog power necessary to drive existing synchro-type navigation instruments.

e. Numerous cables, plugs, receptacles and adapters necessary to connect system elements and to connect the system to aircraft wiring.

4.1.4 C-141A Vehicle Environment

The vehicle environment in the C-141A transport-type aircraft is generally benign. Vibration levels are low, and except for the antenna/preamplifier assembly, the equipment will be installed in pressurized and air-conditioned areas. The antenna/preamplifier assembly, in the center wing area, could be subjected to altitude (pressure) extremes of 40,000 feet and operating temperature extremes of -70° to +68°C. This temperature span exceeds that presently specified for GPS user equipment.

4.1.5 C-141A Problem Areas

No significant problem areas associated with the C-141A integration effort were identified.

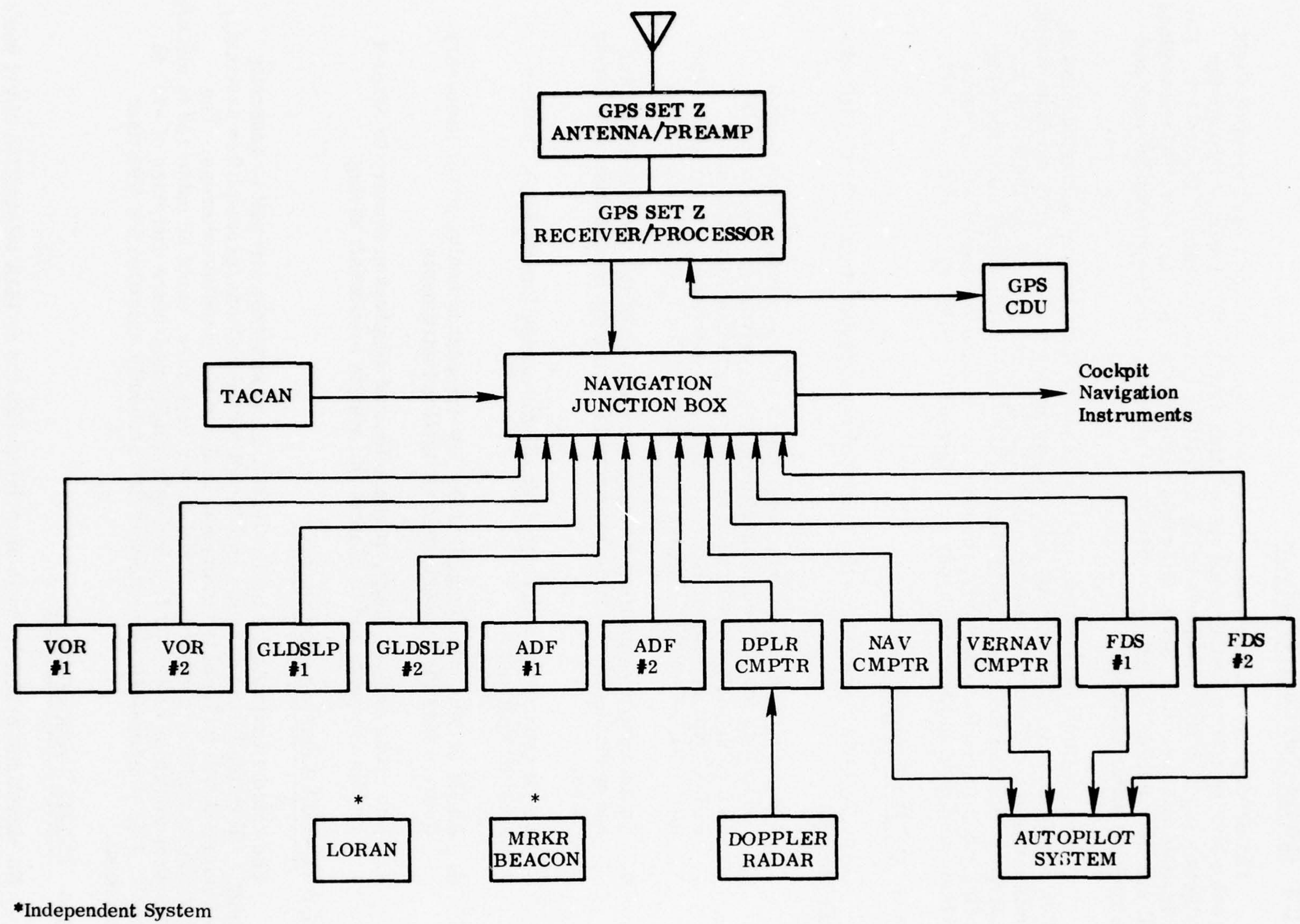


Figure 4-2. Simplified Block Diagram, Radio Navigation System of GPS Test Installation, C-141A Aircraft

4.2 KC-135A INTEGRATION

4.2.1 KC-135A Group B Installation

The suggested installation of the three LRUs of Set Z into the KC-135A is as follows:

a. The Set Z receiver/processor in a common mounting with the IM, is located on the floor of the electronics compartment. The equipment replaces the TACAN receiver/transmitter unit and its mounting.

b. The Set Z control/display unit is mounted on the navigator's table, since the cockpit pedestal is not configured to accept control panels, and other cockpit locations appear unfeasible.

c. The Set Z antenna/preamplifier assembly is located on top of the aircraft near FS 375, where it replaces the TACAN top antenna. The preamplifier extends into the fuselage pressurized area; see Section 4.2.4 for further discussion.

4.2.2 KC-135A Functional Interfaces

The Set Z receiver/processor and Integration Module will connect to the KC-135A aircraft flight director and navigation instruments via existing TACAN wiring through the flight director junction box, as shown in the simplified block diagram of Figure 4-3. For navigation data selection, Set Z will replace the TACAN set. A new wiring harness must be installed to connect the CDU.

TAS and altitude data will be input to Set Z via special wiring harnesses, which couple into aircraft circuitry without damage or modification to existing wiring. Semi-flexible foam-dielectric coaxial cable will be installed between the electronics compartment and the fuselage overhead near FS 375 to connect receiver/processor and antenna/preamplifier. A spare RGA annunciator panel light in the cockpit may be connected for GPS degraded-mode alert.

4.2.3 KC-135A Group A Items

Group A items required for the indicated Set Z installation in the KC-135A aircraft include:

a. A receiver/processor mounting, which incorporates rack-and-panel connectors for plug-in connection of the receiver/processor and IM elements, plateform vibration isolators, type C holddowns, and ARINC-type cooling orifices. External connections for interface wiring utilize MIL-C-83723 circular connectors at the rear of the mounting.

b. An antenna/preamplifier mounting, consisting of the structural doubler and mounting hardware to be specified during the installation engineering phase.

c. An IM converter, which provides digital-analog interfacing with other aircraft systems.

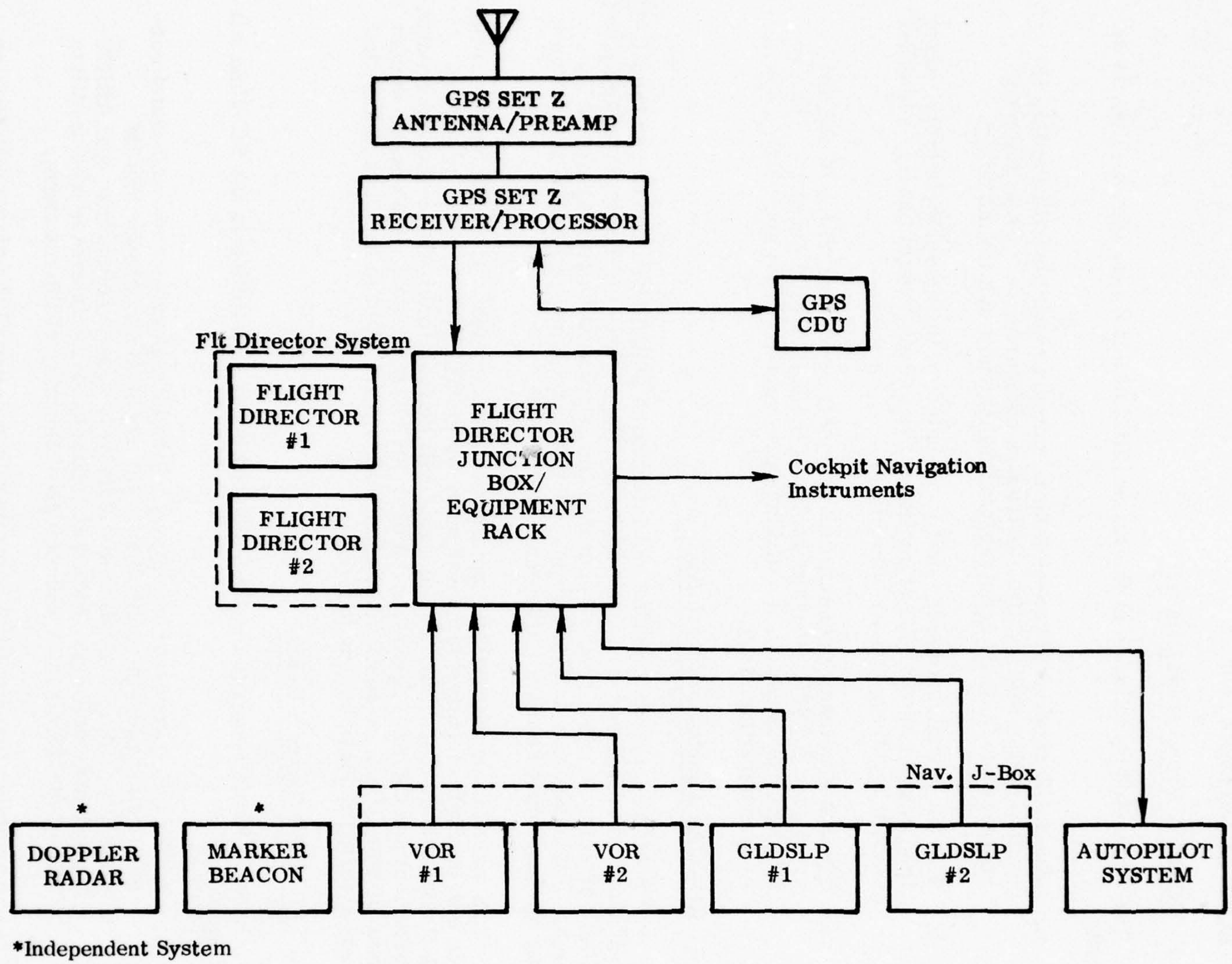


Figure 4-3. Simplified Block Diagram, Radio Navigation System, GPS Test Installation, KC-135A Aircraft

d. An IM driver, which supplies the low-impedance analog power necessary to drive existing synchro-type navigation instruments.

e. Numerous cables, plugs, and receptacles necessary to connect system elements and to connect the system to ship's wiring.

4.2.4 KC-135A Vehicle Environment

The vehicle environment in the KC-135A aircraft is generally benign. Vibration levels are low, and except for the antenna, the equipment will be installed in pressurized and air-conditioned areas. The antenna/preamplifier assembly must withstand the cabin pressurization differential of up to 9.4 psi. The antenna operating temperature may range from -70° to 68°C, a range in excess of that presently specified for GPS user equipment.

4.2.5 KC-135A Problem Areas

No significant problem areas associated with the KC-135A integration effort were identified.

4.3 HC-130H INTEGRATION

4.3.1 HC-130H Group B Installation

The suggested installation of the three LRUs of Set Z into the HC-130H is as follows:

a. The Set Z receiver/processor, in a common mounting with the IM, is located in the left avionics equipment rack below the cockpit of the HC-130H aircraft. The equipment replaces the TACAN No. 1 receiver/transmitter unit and its mounting.

b. The Set Z control/display unit is mounted in the HC-130H cockpit on the left forward section of the center console. The TACAN No. 1 control panel is removed, and other panels rearranged to make sufficient space available.

c. The Set Z antenna/preamplifier assembly is located on top of the aircraft at the center wing area near FS 517, where it replaces the TACAN No. 1 top antenna. The compartment into which the preamplifier extends is unpressurized and unheated; see Section 4.3.4 for further discussion. Some GPS antenna pattern obstruction may be experienced due to the AN/ARD-17 radome and antenna forward of the selected antenna location. However, relocation of the Set Z antenna further aft would not appear to improve total hemispherical coverage.

4.3.2 HC-130H Functional Interfaces

The Set Z receiver/processor and integration module will utilize the existing TACAN No. 1 wiring harness to connect into the HC-130H aircraft flight director system and the navigation flight instruments. Connections are made directly into the TACAN No. 1 coupler plug, and signals are routed variously through the TACAN junction box and the navigation switching system, as shown in the simplified block diagram of Figure 4-4.

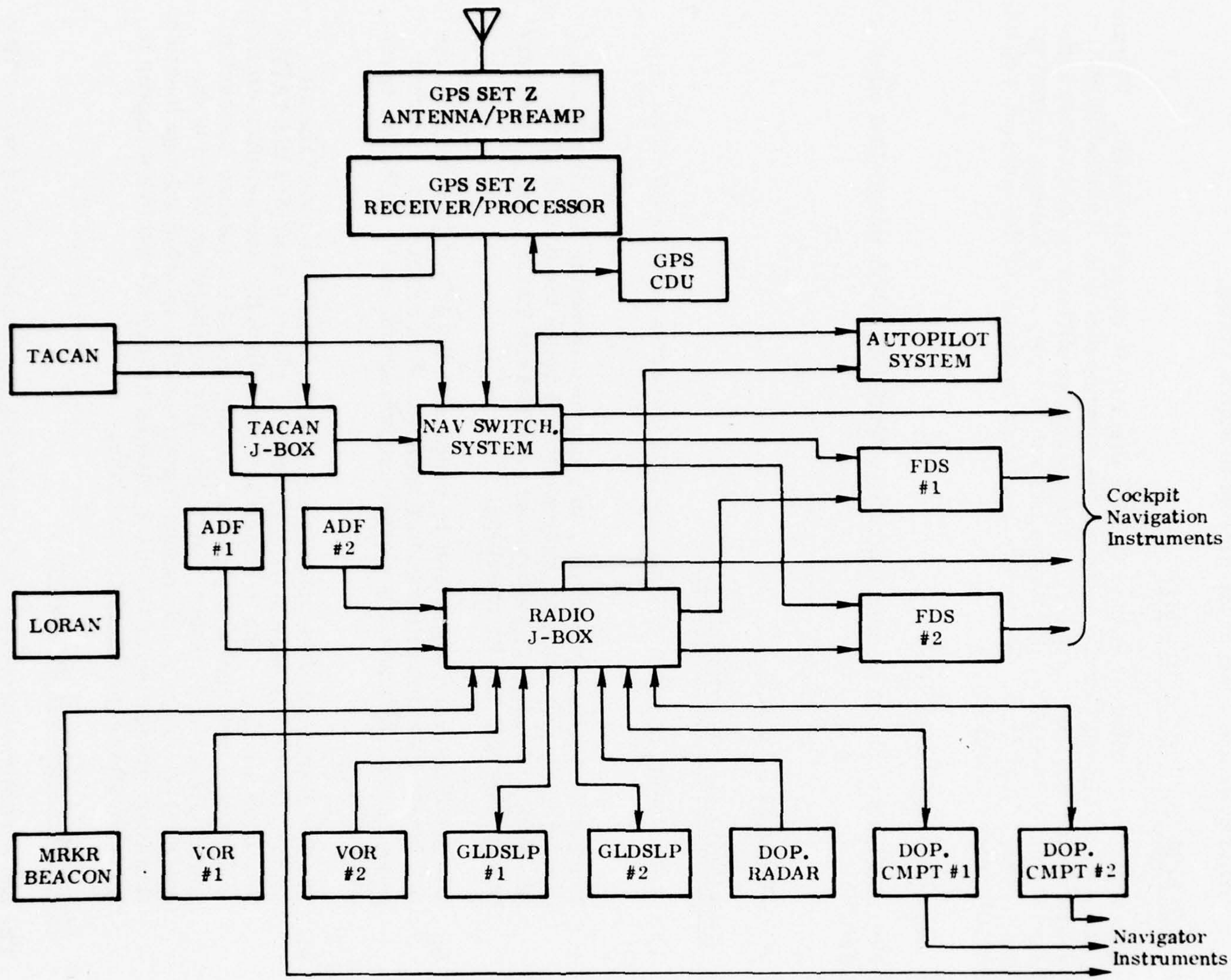


Figure 4-4. Simplified Block Diagram, Radio Navigation System, GPS Test Installation, HC-130H Aircraft

The CDU will connect to the receiver/processor unit via the existing TACAN No. 1 control panel wiring. A special wiring harness will be connected to a terminal strip in the cockpit pedestal for altitude data input to the GPS equipment. True airspeed inputs, degraded mode light, and distance flag displays are not available in the HC-130H aircraft and will not be utilized. Semiflexible foam-dielectric coaxial cable will be installed between the avionics equipment rack and the pressure bulkhead at the fuselage overhead (near the wing leading edge) to connect the receiver/processor and antenna/preamplifier.

4.3.3 HC-130H Group A Items

Group A items required for the indicated Set Z installation in the HC-130H aircraft include:

a. A receiver/processor mounting, which incorporates rack and panel connectors for plug-in connection of the receiver/processor and IM elements, plateform vibration isolators, type C holddowns, and ARINC-type cooling orifices. External connections for interface wiring utilize MIL-C-83723 circular connectors at rear of the mounting.

b. An antenna/preamplifier mounting, consisting of the structural doubler and mounting hardware to be specified during the installation engineering phase.

c. An IM converter, which provides digital-analog interfacing with other aircraft systems.

d. An IM driver, which supplies the low-impedance analog power necessary to drive existing synchro-type navigation instruments.

e. Numerous cables, plugs, receptacles and adapters neccessary to connect system elements and to connect the system to ship's wiring.

4.3.4 HC-130H Vehicle Environment

The vehicle environment in the HC-130H transport-type aircraft is generally benign. Vibration levels are low, and except for the antenna/preamplifier assembly the equipment will be installed in pressurized and air-conditioned areas. The antenna/preamplifier assembly, in the center wing area, could be subjected to altitude (pressure) extremes of 30,000 feet and temperature extremes of -65° to +68° C. This temperature range exceeds that presently specified for GPS user equipment.

4.3.5 HC-130H Problem Areas

No significant problem areas associated with the HC-130H integration effort were identified.

4.4 HH-53B/C INTEGRATION

4.4.1 HH-53B/C Group B Installation

The suggested installation of the three LRUs of Set Z into the HH-53B/C is as follows:

a. The Set Z receiver/processor, in a common mounting with the IM, is located in the right-side nose avionics bay of the HH-53B/C aircraft. The equipment replaces the ARN-65 TACAN receiver/transmitter unit and its mounting, but is reoriented for a transverse installation.

b. The Set Z control/display unit is mounted in the cockpit in the front center area of the center console. The TACAN and the LF/ADF control panels are removed, and other panels rearranged to make sufficient space available.

c. The Set Z antenna/preamplifier assembly is located on the top surface of the horizontal stabilizer. The preamplifier extends into the void between stabilizer beams. The stabilizer skin will be modified to accept and mount the assembly, and to incorporate an access plate to permit field servicing. This antenna location is not under the main rotor shadowing which would be a problem for a fuselage-mounted unit. Shadowing, however, will still exist from the left-side tail rotor.

4.4.2 HH-53B/C Functional Interfaces

The Set Z receiver/processor and Integration Module will connect to the HH-53B/C aircraft navigation instruments via the existing TACAN wiring through the relay box. CDU connections will also use the existing TACAN wiring harness. There is no interface with the flight director system. Figure 4-5 depicts the helicopter radio navigation system with the Set Z installation. For navigation data selection, GPS will replace TACAN in the cockpit legends.

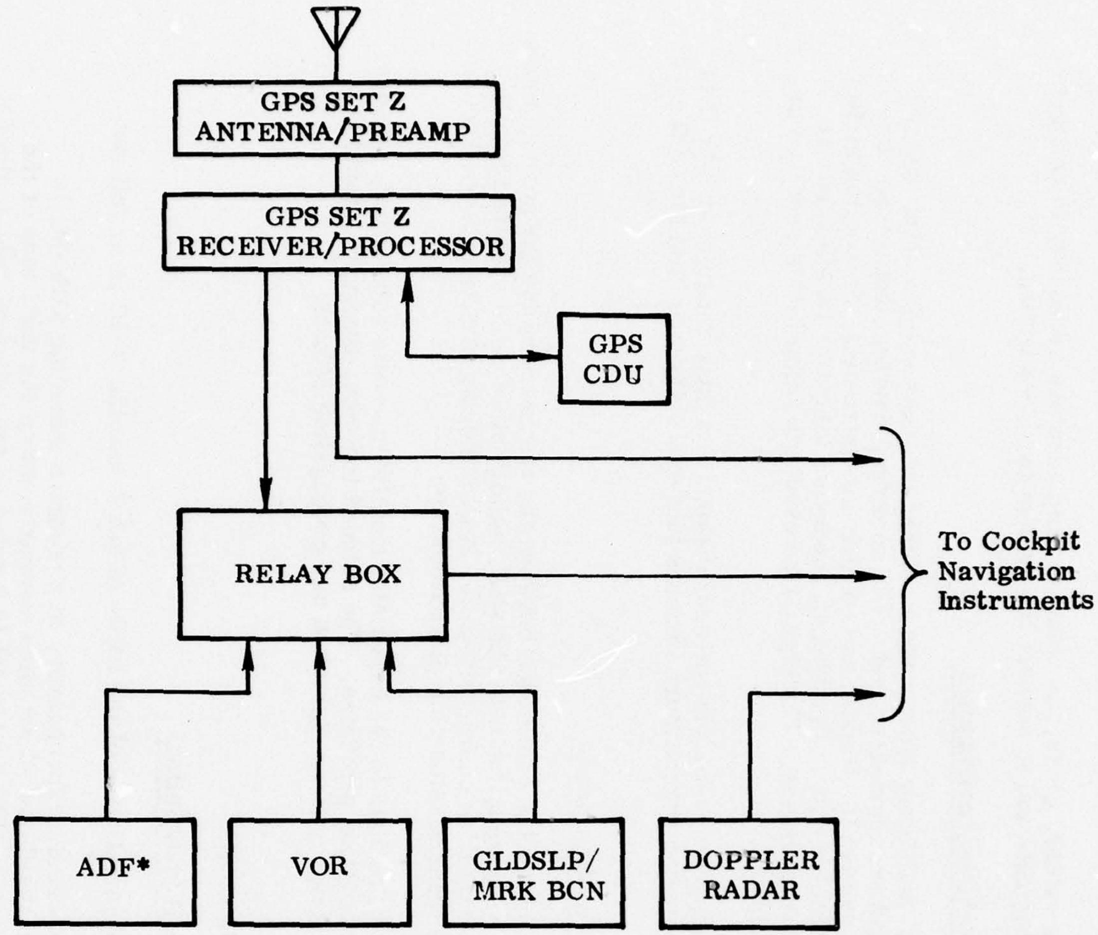
TAS and altitude data will be input into the GPS Set Z via special wiring harnesses, which couple into aircraft circuitry without damage or modification to existing wiring. Semiflexible foam-dielectric coaxial cable will be installed between the right-side nose avionics bay and the tail structure at the top of the pylon to connect the receiver/processor and antenna/preamplifier. A spare caution panel light in the cockpit may be connected for GPS degraded-mode alert.

4.4.3 HH-53B/C Group A Items

Group A items required for the indicated Set Z installation in the HH-53B/C aircraft include:

a. A receiver/processor mounting, which incorporates rack-and-panel connectors for plug-in connection of the receiver/processor and IM elements, plateform vibration isolators, type C holddowns, and ARINC-type cooling orifices. External connections for interface wiring utilize MIL-C-83723 circular connectors at the rear of the mounting.

b. An antenna/preamplifier mounting, consisting of the structural doubler, access panels and mounting hardware to be specified during the installation engineering phase.



*ADF control box may be removed for test.

Figure 4-5. Simplified Block Diagram, Radio Navigation System, GPS Test Installation, HH-53 Aircraft

c. An IM converter, which provides digital-analog interfacing with other aircraft systems.

d. An IM driver, which supplies the low-impedance analog power necessary to drive existing synchro-type navigation instruments.

e. Numerous cables, plugs, receptacles, and adapters necessary to connect system elements and to connect the system to ship's wiring.

4.4.4 HH-53B/C Vehicle Environment

The HH-53B/C helicopter types have a limited environmental control system (vents and heater) and are unpressurized. The operating environment for Set Z is therefore generally subject to climatic and outside-air extremes. No cooling airflow is provided in the avionics bays. In addition, moderate vibration levels occur at rotor-blade-related frequencies. The highest relevant vibration levels reported are on the horizontal stabilizer.

Operating temperatures for the antenna/preamplifier may range from -30° C to 71° C. This high operating temperature exceeds that presently specified for GPS user equipment.

4.4.5 HH-53B/C Problem Areas

The long and obstructed cable runs between the tail antenna and the nose avionics bay will be difficult to accomplish with the stiff, semiflexible cable required for its low-loss, phase preservation characteristics. Manufacturing breaks must be kept to a minimum to avoid transmission-line discontinuities.

Structural modifications to the horizontal stabilizer, while substantial, are not likely to present installation problems. The antenna location, however, should be investigated to determine pattern distortion and propagation effects.

4.5 P-3C INTEGRATION

4.5.1 P-3C Group B Installation

The suggested installation of the LRUs of Set Z into the P-3C is as follows:

a. The Set Z receiver/processor, in a common mounting with IM, is located in the C-1/C-2 avionics compartment on the right side of the P-3C aircraft. The equipment is located on the outboard side of shelf B, behind the navigator's chair.

b. The Set Z control/display unit is mounted in the P-3C cockpit on the left side of the center console below the power levers. The pilot's camera control panel is removed and other panels rearranged to make sufficient space available.

c. The Set Z antenna/preamplifier assembly is located on top of the aircraft near FS 460. The preamplifier extends into the fuselage pressurized area; see Section 4.5.4 for further discussion.

4.5.2 P-3C Functional Interfaces

Set Z will be installed in the P-3C without removal of the existing TACAN. To display the GPS navigation data on the flight instruments, a means of selecting the instrument input (TACAN or GPS) will be needed. A selector panel and relay box is suggested, to permit positive selection of the desired system by the pilot, as shown in the block diagram of Figure 4-6. Existing TACAN wiring will be utilized for the instrument interface and system connection from the relay box into the navigation interconnection box.

TAS and altitude data will be input into Set Z via special wiring harnesses, which couple into aircraft circuitry without damage or modification to existing wiring. Semiflexible, foam-dielectric coaxial cable will be installed between the avionics compartment and the antenna/preamplifier assembly along the right side of the fuselage overhead. A spare annunciator panel light in the cockpit may be connected for GPS degraded-mode alert.

4.5.3 P-3C Group A Items

Group A items required for the indicated Set Z installation in the P-3C aircraft include:

a. A receiver/processor mounting, which incorporates rack and panel connectors for plug-in connection of the receiver/processor and IM elements, plateform vibration isolators, type C holddowns, and ARINC-type cooling orifices. External connections for interface wiring utilize MIL-C-83723 circular connectors at the rear of the mounting.

b. An antenna/preamplifier mounting, consisting of the structural doubler and mounting hardware to be specified during the installation engineering phase.

c. An IM converter, which provides digital-analog interfacing with other aircraft systems.

d. An IM driver, which supplies the low-impedance analog power necessary to drive existing synchro-type navigation instruments.

e. A GPS/TACAN relay box, which permits connection of either the TACAN set or the GPS Set Z to the aircraft navigation instruments; see Figure 4-7.

f. A GPS/TACAN selector panel, for pilot control of the relay box selection.

g. Circuit breakers, for power connection of the GPS equipment.

h. Numerous cables, plugs, and receptacles necessary to connect system elements and to connect to ship's wiring.

4.5.4 P-3C Internal Environment

The vehicle environment of the P-3C aircraft is generally benign. Vibration levels are low, and the GPS equipment will be installed in pressurized and

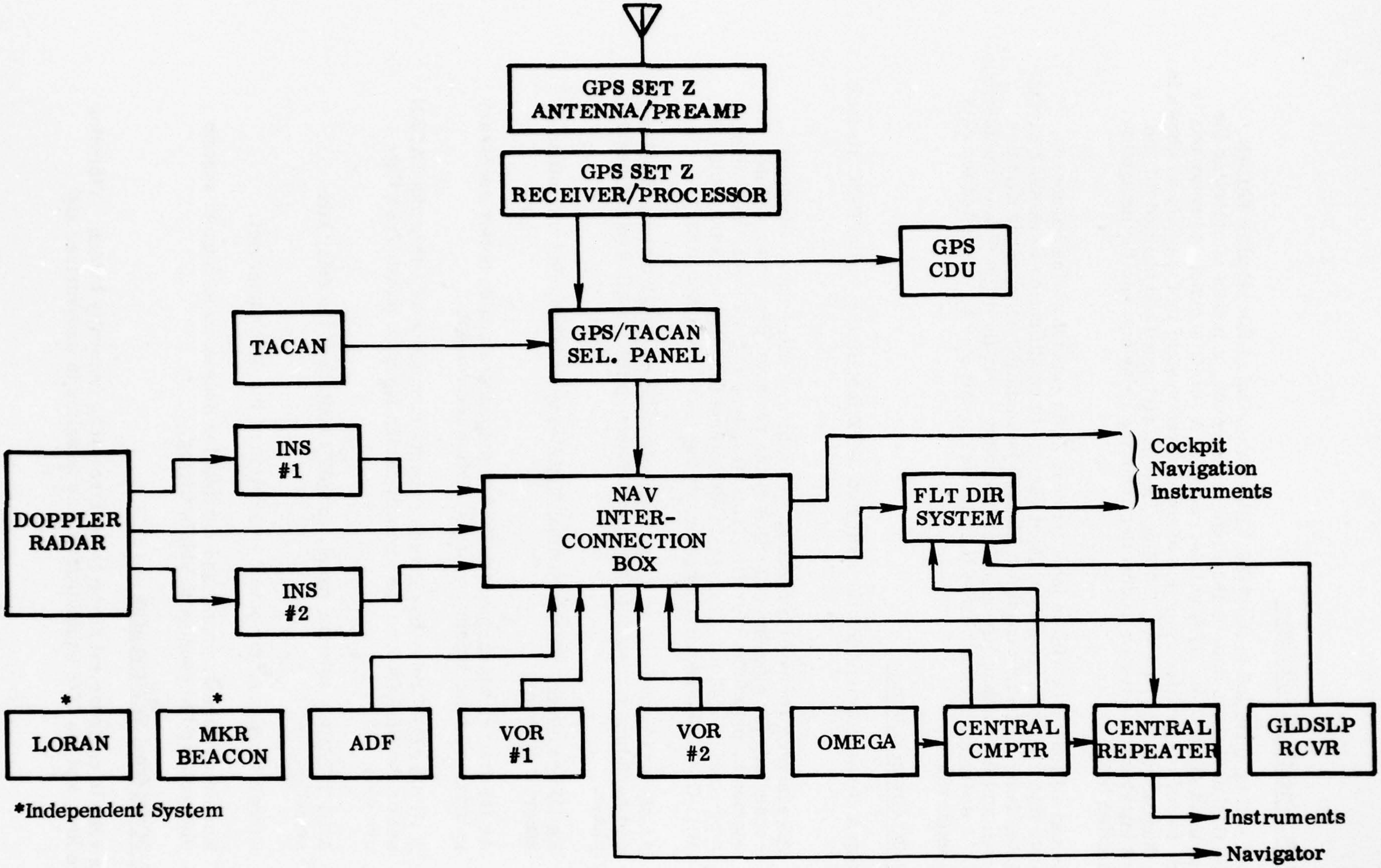


Figure 4-6. Simplified Block Diagram, Radio Navigation System, GPS Test Installation, P-3C Aircraft

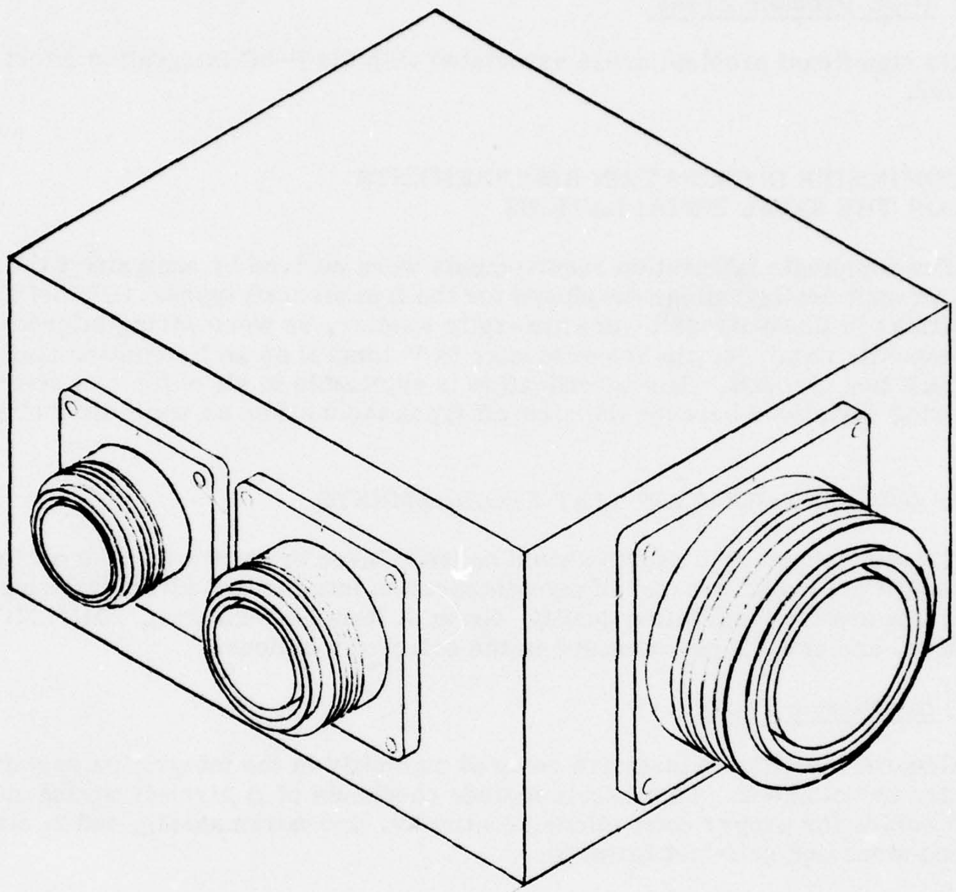


Figure 4-7. GPS/TACAN Relay Box, P-3C Installation

air-conditioned areas. The antenna/preamplifier installation will penetrate into the pressurized fuselage. The assembly must maintain pressure integrity and withstand a pressurization differential of up to 5.5 psi. Antenna operating temperatures may range from -65°C to 68°C, a range which exceeds that presently specified for GPS user equipment.

4.5.5 P-3C Problem Areas

No significant problem areas associated with the P-3C integration effort were identified.

4.6 COMPOSITE INTEGRATION REQUIREMENTS FOR THE IOT&E INSTALLATIONS

The composite integration requirements were derived by analysis of the individual aircraft configurations developed for the five aircraft types. GPS Set Z installations in these aircraft were generally similar, as were wiring interconnections. The composite requirements are presented in Volume II as an integration specification for IOT&E test aircraft. The specification is applicable to all of the test aircraft, with wiring variations between the aircraft types included as an appendix thereto.

4.7 SPECIAL INTEGRATION TEST REQUIREMENTS

Certain special test efforts should be undertaken to ensure that the performance of Set Z will not suffer because of poor integration into the test aircraft during IOT&E. These tests involve installation quality, Group A item performance, EMI/EMC evaluation, and antenna performance in the selected locations.

4.7.1 Installation Tests

General installation tests are covered explicitly in the integration specification presented in Volume II. These tests include checkouts of 1) aircraft wiring and coaxial cables for proper connections, continuity, and workmanship; and 2) all Set Z mode functions and self-test features.

4.7.2 Group A Item Performance

Proper integration of Set Z will require correctly designed and configured Group A items appropriate to the host aircraft. Of particular importance are the operation of the Integration Module (converter and driver elements); and in the P-3C, the performance of the GPS/TACAN relay box. Receiver/processor mounting intra-wiring will be tested as part of the aircraft wiring check. Integration Module tests are covered in Volume III. These tests include:

a. Normal operation of Set Z and all interfacing host vehicle avionics

b. Degraded-performance operation of Set Z

c. Set Z compatibility during the various switching combinations of the flight director mode control

d. The extent of possible Integration Module electromagnetic compatibility problems.

The P-3C GPS/TACAN relay box will be tested not only with Set Z, but also with the TACAN inputs to aircraft instrumentation to ensure proper operation.

4.7.3 EMI/EMC Evaluation

A possibility exists for noise interference with Set Z from the aircraft IFF transmissions. Interference may also be coupled into CDU wiring, which is unshielded; or caused by noise on the input power wiring. Instability problems may be generated by paralleling dissimilar synchro loads from the IM driver in some aircraft. These possibilities should be investigated by simultaneous operation of Set Z and the suspected interfering system in the various modes.

4.7.4 Antenna Performance

The Set Z antenna location in the HH-53B/C helicopter may present special problems. The suggested installation is on top of the aircraft horizontal stabilizer. Although offering the least obstructed field of view, this location has significant drawbacks, and performance degradation is still probable. The antenna is not under the main rotor, but reception may be affected by the proximity of the tail rotor on the left side.

Antenna pattern tests should be made of the HH-53B/C installation with both main and tail rotors in motion. It is suggested that tests also be performed with an antenna located on the after fuselage top under the main rotor to see if this alternate location is feasible.

4.8 CONTENTS OF VOLUME II

Further details on the material presented in this section can be found in Volume II of this report. For convenience, the table of contents of that volume is reproduced herein as Figure 4-8.

CONTENTS

Figure 4-8. Table of Contents, Volume II (Sheet 1 of 2)

Figure 4-8. (Sheet 2 of 2)

5
INTEGRATION MODULE DEFINITION SUMMARY

5.1 IM DEFINITION STUDY BACKGROUND

One of the primary goals of the GPS User Equipment Set Z integration task was the definition of an Integration Module as an interface device between Set Z and selected indicators or displays aboard the specified test aircraft. Specifically, the performance characteristics and system integration requirements for the IM were defined, and a form, fit, and function specification was written for use by the GPS JPO. The specification was developed to the "black box" level, with input and output characteristics specified.

Detailed circuit design and packaging of the IM were not required by this task. However, to verify the feasibility of an IM and to validate the specification, ARINC Research investigated the circuit design requirements for the IM described in the form, fit, and function specification. In particular, the following tasks were conducted, the details of which can be found in the referenced sections of Volume III:

a. Determined the avionic systems that the IM could service (Sections 1 and 2).

b. Established the feasibility of the IM based on host vehicle constraints (Section 2).

c. Defined the design requirements for the IM (Section 3).

d. Determined the impact of the IM on Set Z and the user vehicle (Sections 3.5 and 3.6)

e. Determined any design and system integration problem areas (Sections 3 and 7).

f. Determined what special testing would be required for the IM (Section 5).

g. Prepared a form, fit, and function specification for the IM (Section 6 and Appendix A).

Additionally, other tasks were performed that helped to determine alternate approaches to the design of an IM and substantiate the specification requirements. They included the following:

a. Investigated the detailed circuit design requirements for each function of the IM (Section 3).

b. Determined the power requirements for the IM based on the integration requirements established for the worst-case load (Section 3.3).

c. Performed a budgetary cost analysis for the design investigated (Section 3.4).

d. Identified four alternative approaches to the functional design of the IM (Section 4).

e. Prepared signal characteristic sheets for each IM to aircraft avionics input/output signal for each aircraft (Appendix B).

5.2 TEST AIRCRAFT REQUIREMENTS

Documentation on the five test aircraft was reviewed to determine the electrical signal interface requirements for the IM. Both aircraft and avionics technical orders were studied to ascertain the feasibility of integrating Set Z into the TACAN location. This study revealed that no major wiring modifications to the test aircraft are needed to drive the same indicators that the TACAN set was driving. The same indicators provide an adequate display of the navigation situation when using GPS signals. However, these displays are limited to the horizontal navigation situation only; to display the vertical GPS navigation data, wiring modifications and the addition of switching circuits would be required in the test aircraft.

Before limiting the Set Z integration to TACAN displays only, an evaluation was made of the feasibility of driving other horizontal and/or vertical instruments. However, based on the guidance of maintaining an economical integration effort, it was determined that driving other instruments not presently driven by TACAN would require extensive modifications to the existing aircraft wiring plus the addition of control panels and switching circuits. Another factor presently mitigating against the use of vertical displays is that of flight safety. It is recommended that vertical instruments not be driven with GPS signals until further study is performed in this area to determine its operational desirability and impact on flight safety.

The avionics of the different test-aircraft are quite similar as far as the TACAN interface is concerned. Table 5-1 lists the TACAN systems for each aircraft to be replaced physically with Set Z (or in the case of the P-3C, functionally), and the primary instruments. The output driver signals from these different TACAN systems are identical, even though the number of instruments driven and the switching arrangement for routing the interface signals to these instruments are different. From this information it was determined that only a single Integration Module need be defined for all five test aircraft. The only area that would have to be changed to tailor the IM design to a particular aircraft would be in the output drive capability of the IM due to the difference in loads between aircraft. However, it was felt that the difference in the cost of tailoring the design for each aircraft versus a common design based on the worst-case type did not warrant a custom design for each aircraft. Therefore a common or composite IM has been defined.

After analyzing the aircraft avionic systems, block diagrams of the Set Z electrical integration into those systems were generated. Figures 5-1 through 5-5 are system-level block diagrams for each test aircraft, showing the pertinent GPS interface signals and the systems to which they will be routed. The P-3C system is slightly different from the other four types since 1) the Set Z on the P-3C will share the TACAN displays with the existing TACAN set instead of completely replacing it; and 2) the P-3C does not have a BDHI. The HH-53B/C helicopter is also different from the other test types in that it has a flight director indicator and a course indicator instead of an ADI and HSI.

TABLE 5-1. SET Z/TACAN RETROFIT DATA

Aircraft	TACAN Type	Qty.	To Be Repl.	Driven Instruments
C-141A	AN/ARN-21	2	1	1 - AQU-4/A (HSI) 2 - ID-798/ARN (BDHI)
KC-135A	AN/ARN-72	1	1	2 - 331A-8H (HSI) 3 - ID-250/ARN (RMI)
HC-130H	AN/ARN-21	2	1	2 - AQU-2/A (HSI) 2 - ID-1103/ARN (BDHI)
HH-53B/C	AN/ARN-65	1	1	2 - ID-1103/ARN (BDHI) 2 - ID-387/ARN (CDI) 1 - 353-999-0100 (FDI)
P-3C	AN/ARN-84	1	0	3 - ID-1540/A (HSI)

During the investigation of the various aircraft avionic systems, the functional and electrical characteristics of each of the signals were described. These descriptions appear on the Signal Characteristic Sheets of Appendix B, Volume III.

5.3 DESIGN CONCEPT SUMMARY

After system-level requirements for the IM were established, an approach to a detailed circuit design was investigated. The investigation was concerned with:

a. The feasibility and method of implementing each signal type referenced in the IM specification.

b. The availability, size, cost, and power requirements of off-the-shelf solid state digital-to-synchro and synchro-to-digital converters.

c. The power requirements for the IM.

d. The IM size and packaging requirements.

e. The IM cost.

f. Potential Set Z impact areas.

These factors are discussed in the following paragraphs.

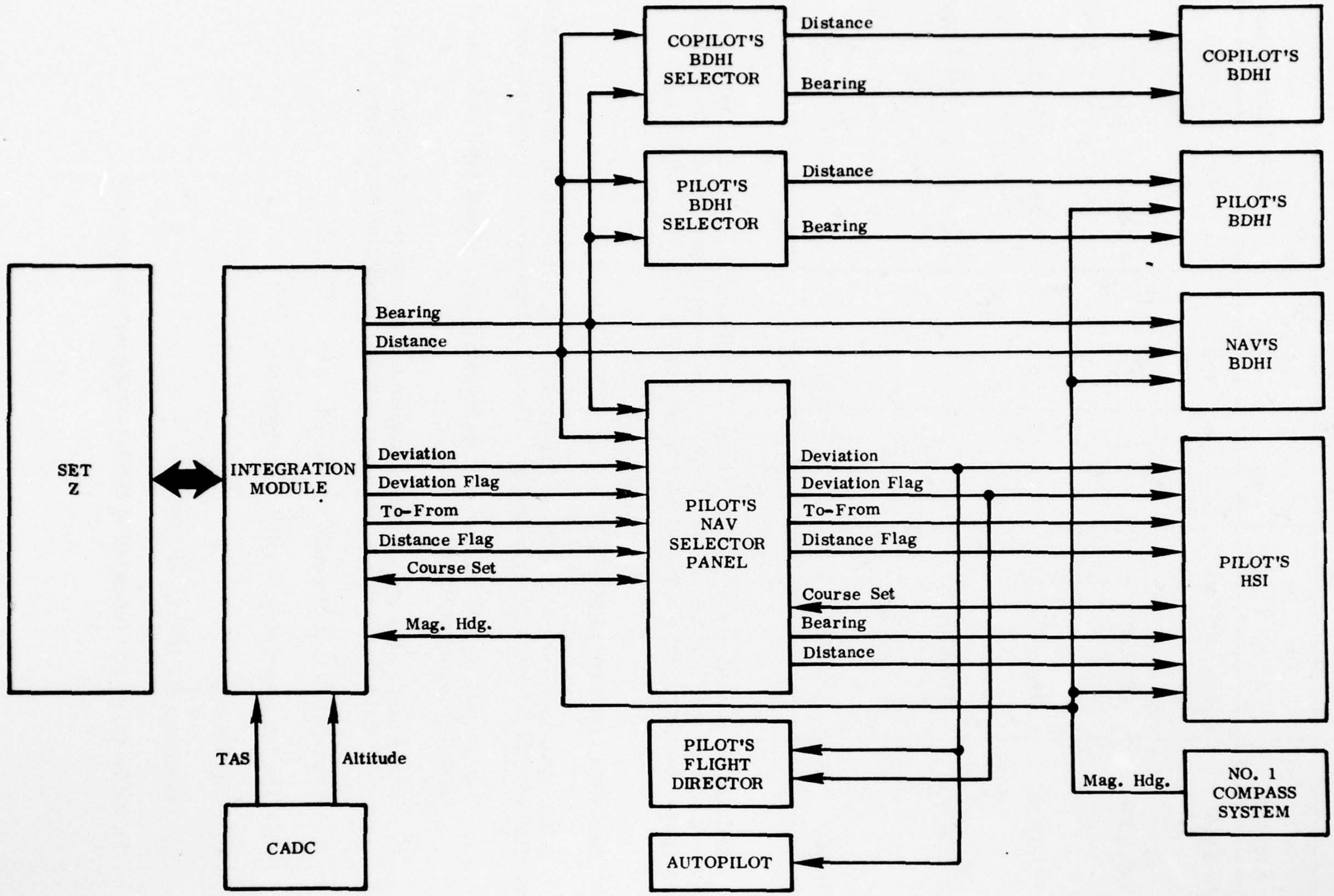


Figure 5-1. Block Diagram, C-141A Interface Signal

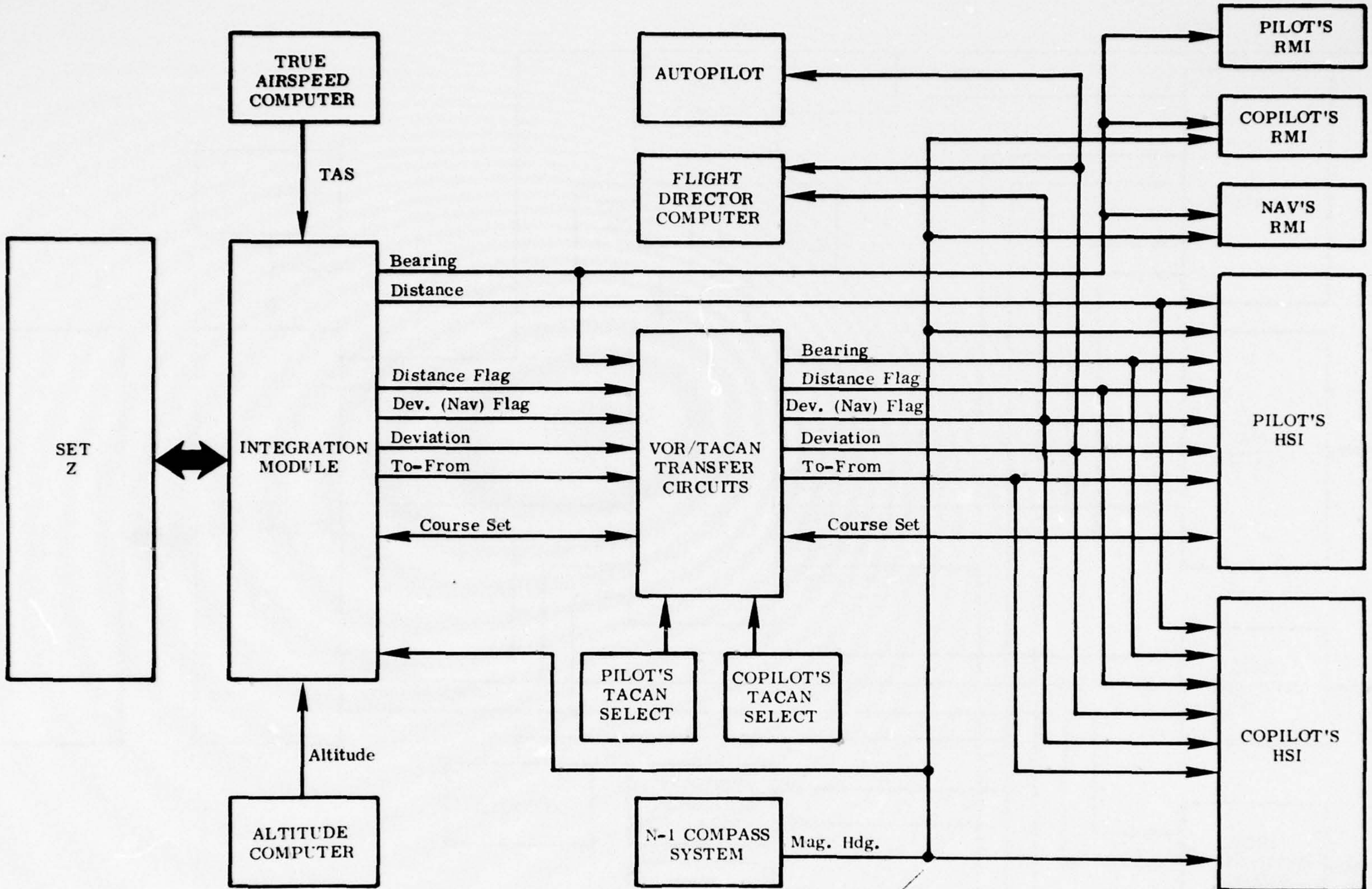


Figure 5-2. Block Diagram, KC-135A Interface Signal

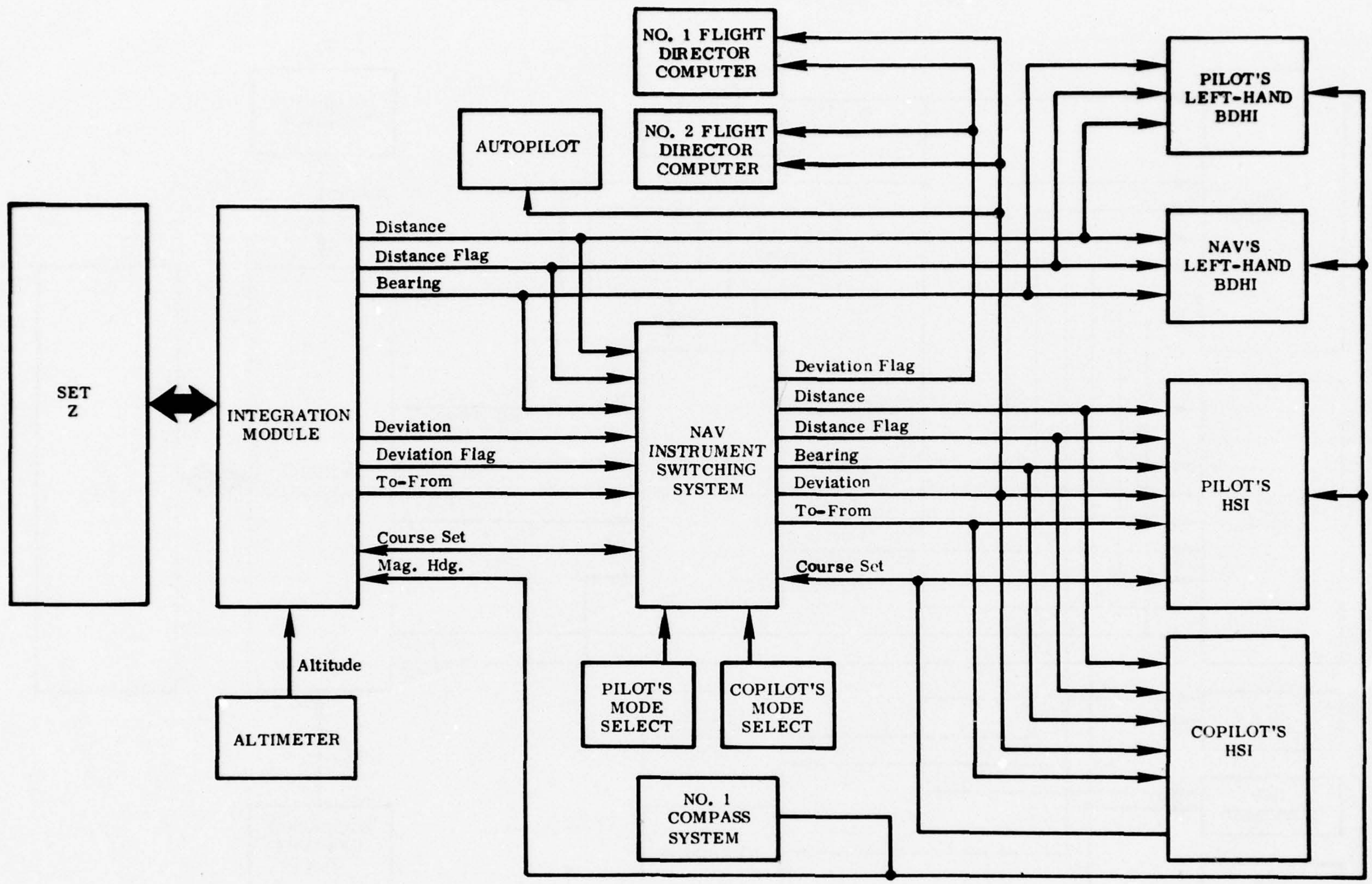


Figure 5-3. Block Diagram, HC-130H Interface Signal

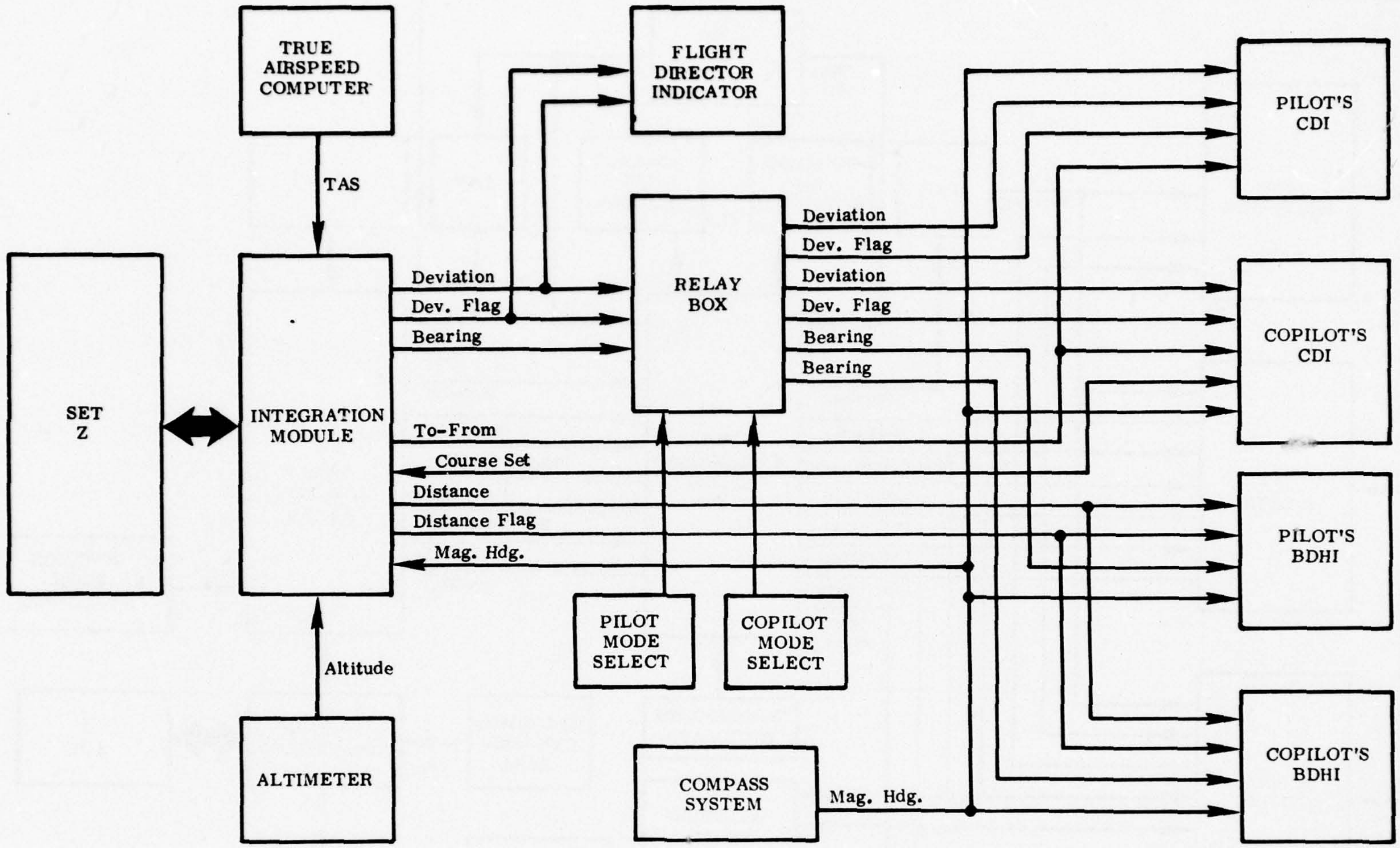


Figure 5-4. Block Diagram, HH-53B/C Interface Signal

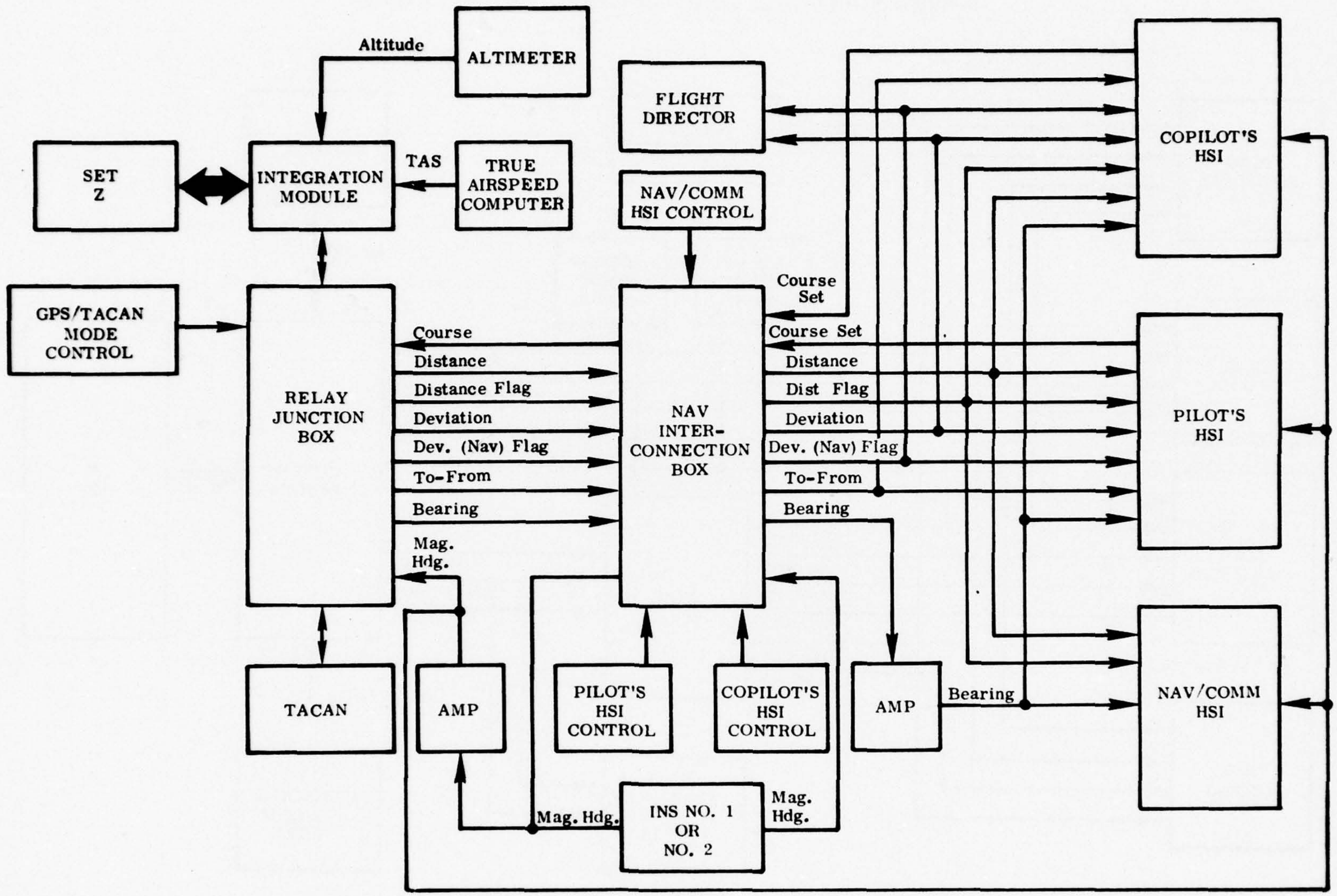


Figure 5-5. Block Diagram, P-3C Interface Signal

5.3.1 Circuit Design

The circuit design requirements for each interface signal were analyzed and an overall block schematic (see Figure 5-6) was derived for the IM configuration specified in the IM form, fit, and function specification. The circuits shown in the schematic can be conveniently divided into output and input circuits. The output circuits convert the digital signals from Set Z into analog format for driving the various avionic instruments. These signals are described in Table 5-2. Conversely, the input signals are those from the test aircraft avionics that the IM converts into digital format for Set Z. The input signals are described in Table 5-3.

Designs other than the one on which this study focused can be derived from the requirements of the IM specification. For example, different schemes of multiplexing the input and output signals can be employed.

5.3.2 Power Requirements

The power requirements of individual IM circuits were calculated and combined into a total dc power requirement for the IM. The power values are based on the load conditions for the worst case aircraft , the HC-130H. The total average power needed by the IM is 98 watts, while the total peak power is 166 watts. Most of this power will be used to drive the bearing and distance loads – in particular, the BDHI circuits.

During the study the assumption was made that the dc power source for the IM would be the Set Z power supply. Therefore, circuit design investigations to include the power supply as part of the IM were not considered or called out in the IM specification. However, based on the large amount of power required for the IM, it now appears desirable to include the IM power supply with the IM design requirements.

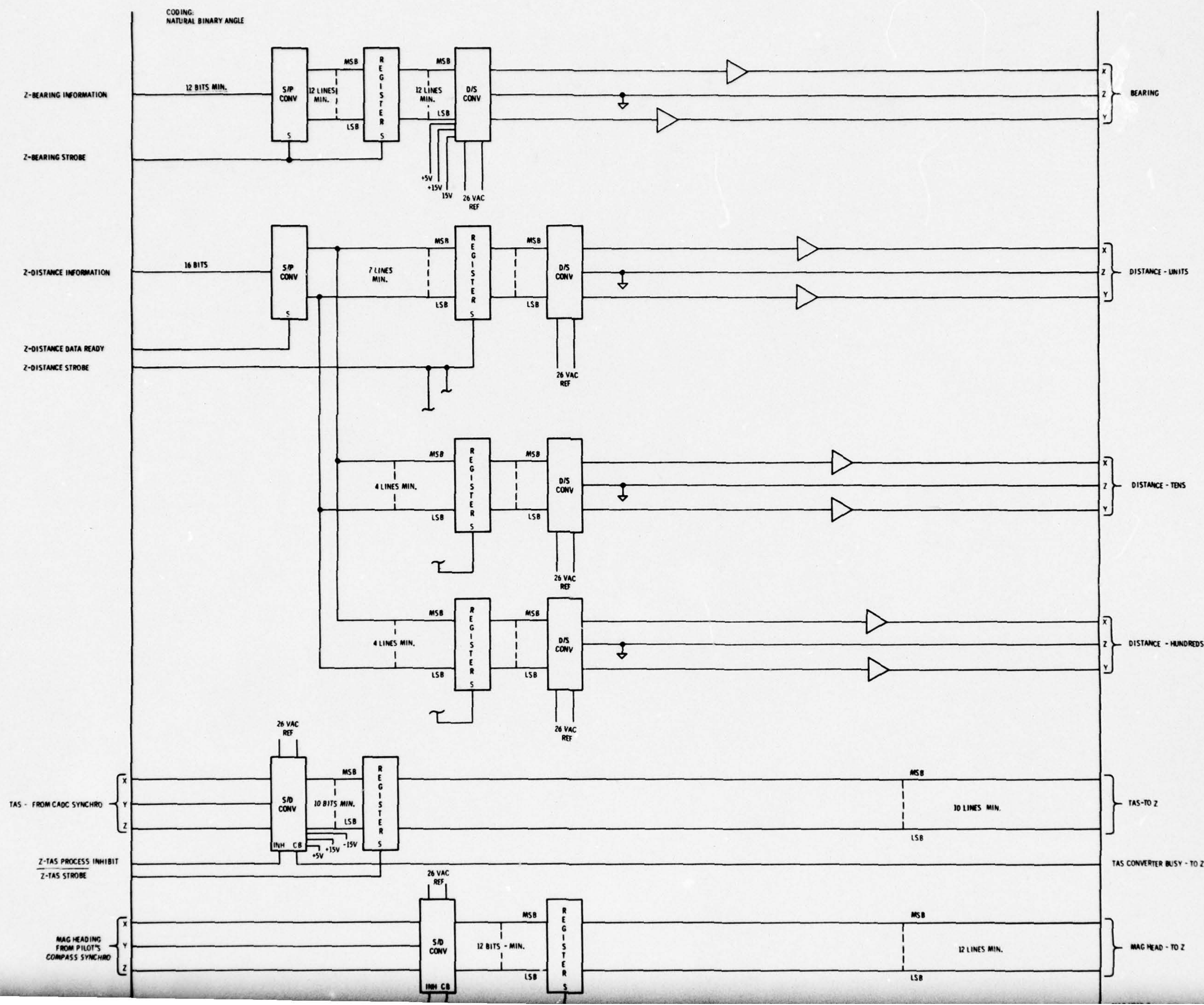
5.3.3 Size and Packaging

Based on the circuit design approach taken in this study, it was determined that IM size and heat dissipation problems precluded mounting that module internally to the Set Z receiver/processor LRU. It was also established that the most convenient IM packaging arrangement would consist of dividing the IM into two separate boxes – one containing the converter circuitry and the other the output driver circuitry (and possibly the IM power supply). Both boxes would be mounted on the same mount as Set Z, as illustrated in Figure 4-1. The converter box would mount alongside the receiver/processor and the driver box behind it. The mount would be the same 1ATR size as the existing TACAN mounts.

Again, this approach is offered as only one solution to the packaging arrangement for the circuit design concept presented in Volume III. It is based on the development of a prototype IM that makes maximum use of off-the-shelf modules. Other arrangements are possible, depending on the circuit design approach taken.

5.3.4 Cost

A limited market survey was made to determine the hardware cost and availability of the solid-state converters required for the IM design described in Volume III. Several manufacturers produce off-the-shelf digital-to-synchro and synchro-to-digital modules, but the company that appeared to have the broadest line of devices was Data Device Corporation. Therefore, the prices for their line of converters were used to derive a cost for the IM design. It was found that for prototype quantities


CODING:
NATURAL BINARY ANGLE
Z-BEARING INFORMATION
Z-BEARING STROBE
12 BITS MIN.
S/P CONV
12 LINES MIN.
MSB
LSB
REGISTER
D/S CONV
+5V
+15V
15V
26 VAC REF
BEARING
Z-DISTANCE INFORMATION
16 BITS
7 LINES MIN.
Z-DISTANCE DATA READY
Z-DISTANCE STROBE
DISTANCE - UNITS
4 LINES MIN.
DISTANCE - TENS
DISTANCE - HUNDREDS
TAS - FROM CADC SYNCHRO
S/D CONV
10 BITS MIN.
INH
CB
-15V
10 LINES MIN.
TAS-TO Z
Z-TAS PROCESS INHIBIT
Z-TAS STROBE
TAS CONVERTER BUSY - TO Z
MAG HEADING FROM PILOT'S COMPASS SYNCHRO
12 BITS - MIN.
12 LINES MIN.
MAG HEAD - TO Z
X
Y
Z

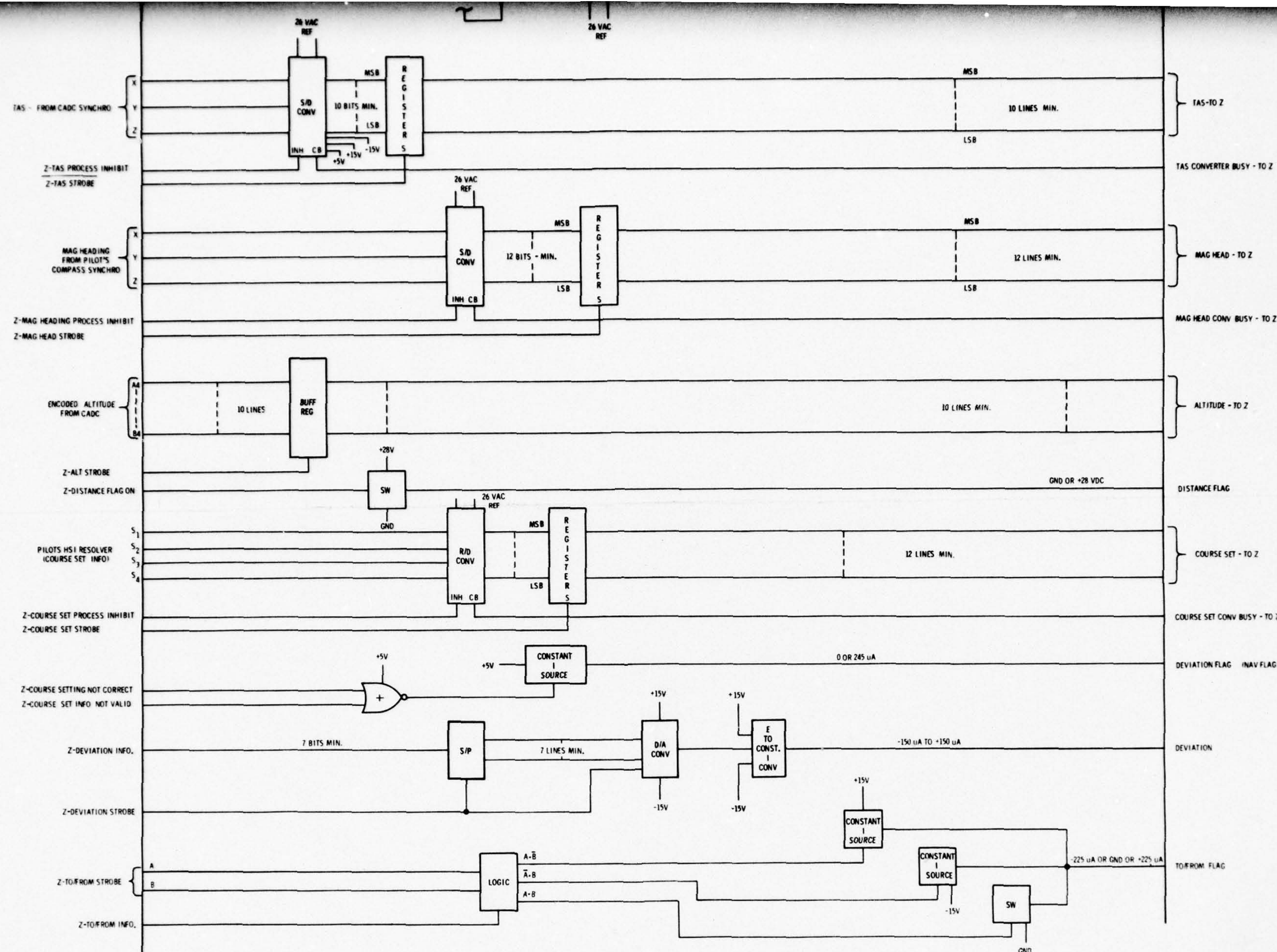


Figure 5-6. IM Block Schematic

TABLE 5-2. IM OUTPUT SIGNALS

Signal/Description	Range	Design Requirements: IM Circuit	Design Requirements: Source
a. Bearing – Azimuth angle from present position to selected waypoint	000.0° to 359.9°	12 bit (BNR), D/S	Bearing pointer synchros
b. Distance – Along-track distance from present position to selected waypoint	000.0 to 999.9 nm		Distance counter synchros (3)
Units		7 bit (BNR), D/S	
Tens		4 bit (BNR), D/S	
Hundreds		4 bit (BNR), D/S	
c. Deviation – Aircraft's deviation to left or right of desired course (E, T, A determines indicator sensitivity)			DC meter movement
Enroute (E)	0 to ±6nm		
Terminal (T)	0 to ±1nm	7 bit (BCD), D/A	
Approach (A)	0 to ±0.1 nm		
d. Distance flag – Warning of unreliable distance data	In-view or out-of-view	1 bit, switch	DC meter movement
e. Deviation flag – Warning of unreliable data or incorrect positioning of course set control	In-view or out-of-view	1 bit to constant I source	DC meter movement
f. To/from – Flag indication of aircraft track toward or away from selected waypoint	To, blank, or from	2 bit (BCD), switched constant I source	DC meter movement
g. Degraded mode (optional) – Annunciator warning of Set Z degraded mode operation	On or off	1 bit, switch	Annunciator light
h. True/mag mode (optional) – Annunciator warning of Set Z operation in true heading or magnetic heading	On = True Off = Mag	1 bit, switch	Annunciator light

TABLE 5-3. IM INPUT SIGNALS

Signal/Description	Range	Design Requirements	
		IM Circuit	Source
a. Course set – Angular position data from course set control indicating course arrow position.	000.0° to 359.9°	12 bit (BNR), R/D	Course set resolver
b. Magnetic heading – Azimuth angle of aircraft centerline relative to magnetic north	000.0° to 359.9°	12 bit (BNR, S/D	Compass system synchro
c. True airspeed – Actual aircraft velocity through air mass	Depends on aircraft (max. = 150 to 650 kt)	10 bit (BNR), S/D	True airspeed synchro
d. Altitude – Aircraft encoded pressure altitude referenced to 29.92 in Hg	Depends on aircraft (max. = 1000 to 60,000 ft)	10 bit ATCRBS code (Gilham)	Shaft angle encoder

(5 to 15), off-the-shelf D/S and S/D modules cost approximately $500 to $700 each. Based on these prices and the total quantity of major electronic components that make up the IM, the hardware cost for the IM design concept presented in Volume III would be approximately $6,215.

5.4 ALTERNATE IM CONFIGURATIONS

As has been pointed out, there are other feasible IM configurations than the one described in detail in Volume III. Three other possibilities were explored to a limited degree. All three design alternatives are based on integrating Set Z into the TACAN location, with the following considerations taken into account:

a. IM cost

b. Integration cost

c. IM impact on Set Z

d. Host vehicle constraints on IM

e. IM impact on host vehicle

f. Integration feasibility

g. Operational considerations

The primary objective of the IM definition study was to define an IM that would provide an economical yet effective integration effort. The configuration selected is thus a compromise approach between a "bare bones" approach of minimal capability and a "full blown" IM that incorporates the vertical navigation functions. The configuration specified is considered the most complex version possible without the requirement for extensive and expensive modifications to the test aircraft.

Table 5-4 describes all four configurations, with 'C' being the baseline configuration described in the functional specification. The following is a summary of the four configurations (see Section 4 of Volume III for greater detail):

a. Austere Configuration (A)

   1) Minimum cost, minimum capability

   2) Could fit into Set Z receiver/processor LRU

b. Budget Configuration (B)

   Duplicates all TACAN capabilities

c. Composite Configuration (C)

   1) Is compromise between budget and deluxe configurations

   2) Defined in product function specification

TABLE 5-4. IM CONFIGURATION COMPARISONS

Function	Configurations			
	A Austere	B Budget	C Composite	D Deluxe
a. OUTPUT TO HOST VEHICLE				
1. Bearing	Yes (Low Accuracy, 2.5°)	Yes (Low Accuracy, 2.5°)	Yes (High Accuracy, 0.5°)	Yes (High Accuracy, 0.5°)
2. Distance, Units	No	Yes	Yes	Yes
3. Distance, Tens	No	Yes	Yes	Yes
4. Distance, Hundreds	No	Yes (0-1)	Yes (0-9)	Yes (0-9)
5. Distance Flag	No	Yes	Yes	Yes
6. Deviation Course (Plus Bank Steering)	Yes	Yes	Yes	Yes
7. Deviation Flag	Yes	Yes	Yes	Yes
8. To-From	Yes	Yes	Yes	Yes
9. Vertical Deviation (Plus Pitch Steering)	No	No	No	Yes
10. Vertical Dev. Flag	No	No	No	Yes
11. Desired Track	No	No	No	Yes
12. Track Angle Error (Ground Track)	No	No	No	Yes
13. True Heading	No	No	No	Yes
14. Altitude	No	No	No	Yes
15. Mag/True Warning	No	No	Yes	Yes
16. Degraded Mode Warn.	No	No	Yes	Yes
b. INPUT TO SET Z				
17. Course Set	No	Yes	Yes	Not Req'd
18. Magnetic Heading	No	Yes	Yes	Yes
19. True Airspeed	No	No	Yes	Yes
20. Altitude	No	No	Yes	Yes

d. Deluxe Configuration (D)

1) Extends Set Z capabilities beyond simple TACAN interface

2) Requires extensive modifications to test aircraft wiring

3) Most versatile configuration to demonstrate Set Z to host vehicle integration during Phase I IOT&E

5.5 IM TEST REQUIREMENTS

In addition to the normal qualification tests required for the IM, consideration should be given to built-in test and integration test requirements. Three methods of incorporating BIT for the IM are presented in Section 5 of Volume III. The recommended method consists of providing test routines in the Set Z software to drive the aircraft instruments to predetermined settings through the IM, thereby allowing a quick assessment of the operational status of that module. Since the failure or lack of the IM is not supposed to interfere with normal operation of Set Z, these BIT routines do not have to be elaborate.

Critical tests for the IM will consist of those integration tests performed on the IM after it has been installed with Set Z in the test aircraft. They should evaluate the following:

a. Normal Set Z operation with the host vehicle avionics

b. Operation with Set Z degraded performance

c. Set Z/IM compatibility with host vehicle avionics during the various combinations of flight director system mode switching

d. Extent of potential IM electronic interference and susceptibility.

5.6 THE IM SPECIFICATION

The culmination of the IM definition study was the generation of a form, fit, and function specification. The specification, prepared in accordance with MIL-STD-490, Type C1a format, was developed at the "black box" level with only input and output characteristics specified. Where applicable, the same specification requirements imposed on user equipment Set Z were also imposed on the IM so as to maintain compatibility between the two items. This specification appears in Appendix A of Volume III.

5.7 SYSTEM IMPACT

5.7.1 IM Impact on Host Vehicle

The impact on the IM due to the avionic configurations of the host vehicles is minimal since all five test aircraft present almost identical interface requirements to Set Z, the only major difference being the number of instruments to be driven. The HC-130H represents the worst-case load to the IM, and therefore the composite IM

output capability has been specified to this aircraft. Tailoring the output capability of the IM for each aircraft does not appear to be an effective solution to reducing the cost of the IM, since the only components affected are the relatively low-cost output amplifiers. However, reducing the instrument load for all aircraft, such as eliminating the driving of BDHIs, would help reduce the cost somewhat, but more importantly would reduce the size of the IM.

It does not appear that the IM will impact on the host vehicle, except possibly in the area of electromagnetic interference. The IM produces relatively large analog currents that could be coupled into adjacent circuits. However, this appears to be easily resolvable with the proper precautions, particularly the effective shielding of interface wiring.

5.7.2 IM Impact on Set Z

The major impact of the IM will be felt by Set Z, particularly in the following areas:

a. Power supply

b. Input signal software processing

c. Built-in-test software routine

If set Z is to supply the dc power for the IM, then the size of the Set Z power supply will have to be increased significantly to accommodate the power requirements for the IM configuration described in this report. This situation can lead to both packaging and heat dissipation problems for the Set Z contractor. However, incorporating the power supply into the IM would allow that device to operate independently of Set Z except for interface signals.

The input signals from the IM to Set Z (magnetic heading, course set, and true airspeed) require special Set Z software processing not originally specified in the user system specification. The magnetic heading and course set signals are required for IM reference purposes to ensure correct placement at the instrument indicators, while the true airspeed signal eliminates a manual input function.

The built-in-test feature for the IM also requires special software routines not originally specified. However, these routines are minimal and should not add substantially to the existing software requirements.

Set Z presents a slight impact on the design of the IM in the interface signal area. At this time the signal structure and format have not been determined. This information is needed so that the IM input circuits can be specified.

None of the impact areas described appear to be overwhelming, and should be resolvable through a joint effort of the Set Z contractor, the GPS JPO, and the IM designer.

5.8 CONTENTS OF VOLUME III

Further details on the material presented in this section can be found in Volume III. For convenience, the table of contents of that volume is produced herein as Figure 5-7.

CONTENTS

Figure 5-7. Table of Contents, Volume III

APPENDIX A
BIBLIOGRAPHY AND SOURCE LIST

A.1 MILITARY SPECIFICATIONS, STANDARDS, AND HANDBOOKS

Specifications

MIL-C-5015D	Connector, Electrical "AN" Type
MIL-W-5088E	Wiring, Aircraft, Installation of
MIL-C-5191B	Computer and Transmitter, True Airspeed Pitot Static, Type A-2
MIL-E-5400N	Electronic Equipment, Aircraft, General Specification for
MIL-C-5809F	Circuit Breaker, Trip-Free, Aircraft, General Specification for
MIL-C-5824A (w/Amend. 1)	Course Indicator ID-250A/ARN
MIL-I-5997B	Instruments and Instrument Panels, Aircraft, Installation of
MIL-R-7060A	Radio Set AN/ARN-21(*)
MIL-I-8700A	Installation and Test of Electronic Equipment in Aircraft, General Specifications for
MIL-I-9229 (w/Amend. 3)	Indicator, Course ID-387/ARN
MIL-S-20708	Synchros, General Specification for
MIL-I-23366A	Indicator, Horizontal Situation ID-1013(*)/A
MIL-F-25173A	Fastener Control Panel, Aircraft Equipment
MIL-I-25992A (w/Amend. 2)	Indicator, Bearing-Distance-Heading, ID-526A/ARN and ID-798/ARN
MIL-F-26685B	Flight Director System, Design and Installation of
MIL-H-26689B (w/Amend. 3)	Horizontal Situation Indicator AQU-2/A

MIL-I-27848A (w/Amend. 3)	Indicator, Horizontal Situation AQU-4/A
MIL-C-38037A	Computer, Central Air Data, CPU-43/A
MIL-C-38240/1C	Computer, Altitude, Altitude Encoding CPU-66/A-1, B-52, KC/C-135, RC-135A, WC-135B, and EC-135A, C, G, H, J, K, L, P
MIL-C-38286 (w/Amend. 2)	Computer, Flight Director CPU-65A
MIL-I-38357A (w/Amend. 1)	Indicator, Bearing-Distance-Heading, ID-1103/ARN
MIL-C-39012B	Connectors, Coaxial, Radio Frequency; General Specification for
MIL-A-81403	Altimeter-Encoder, AAU-21/A
MIL-E-81512	Encoder, Shaft Position to Digital Contact Type, Altitude Reporting
MIL-C-81659A	Connectors, Electrical, Rectangular, Environment Resistant, Crimp Contacts, General Specification for
MIL-R-83205	Radio Set AN/ARN-21C
MIL-R-83442	Receiving Set, Radio AN/ARN-122
MIL-C-83723B	Connectors, Electrical, Circular, Environment Resisting, General Specification for
MS-28027, Rev A	Indicator, Course ID-250A/ARN

Standards

MIL-STD-210B	Climatic Extremes for Military Equipment
MIL-STD-454D	Standard General Requirements for Electronic Equipment
MIL-STD-704A	Electric Power, Aircraft, Characteristics and Utilization of
MIL-STD-810B	Environment Test Methods
MIL-STD-877	Antenna Subsystem, Airborne, Criteria for Design and Location of

Handbooks

MIL-HDBK-214A	Synchros
MIL-HDBK-218	Application of Electrical Resolvers
MIL-HDBK-225(AS)	Synchros, Description and Operation

A.2 AIR FORCE TECHNICAL ORDERS*

1-1A-14	Handbook of Installation Practices for Aircraft and Electronics Wiring
1C-130E-2-8-1	Partial Technical Manual, Maintenance Instructions Radio, Communications & Navigation Systems, C-130E Aircraft (AWADS)
1C-130E-2-8-2	Maintenance Instructions Radio, Communications & Navigation Systems (AN/APN-169A), C-130E Aircraft
1C-130E-4-3	Partial Technical Manual, Illustrated Parts Breakdown for C-130E Aircraft Equipment with Adverse Weather Aerial Delivery Systems, C-130E (AWADS)
1C-130E-4-4	Partial Illustrated Parts Breakdown, C-130
1C-130E-545	Installation of Adverse Weather Aerial Delivery System in C-130 Aircraft
1C-130E-546	Installation of Station Keeping Equipment, C-130
1C-130(H)H-1	Flight Manual, HC-130H Aircraft
1C-130(H)-2-5	Technical Manual, Maintenance Instructions, Instruments, HC-130H Aircraft
1C-130(H)H-2-11	Technical Manual, Maintenance Instructions, Radio, Communications and Navigation Systems, HC-130H Aircraft
1C-130(H)H-2-13	Technical Manual, Maintenance Instructions, Airplane Wiring Diagrams, HC-130H Aircraft
1C-135(K)A-1	Flight Manual for KC-135A Aircraft
1C-135(K)A-2-1	Technical Manual, Organizational (Flight Line) Maintenance Instructions, General Airplane, KC-135A Aircraft
1C-135(K)A-2-9	Organizational (Flight Line) Maintenance Instructions, Instruments, KC-135A Aircraft

*Titles condensed in some instances.

1C-135(K)A-2-10	Technical Manual, Organizational (Flight Line) Maintenance Instructions, Electrical Systems, KC-135A Aircraft
1C-135(K)A-2-11	Organizational (Flight Line) Maintenance Instructions, Radio, Communication, and Navigation Systems, KC-135A Aircraft
1C-135(K)A-2-12-1	Technical Manual, Organizational (Flight Line) Maintenance Instructions, Wiring Diagrams, Electrical, KC-135A Aircraft
1C-135(K)A-2-12-2	Technical Manual, Organizational (Flight Line) Maintenance Instruction, Wiring Diagrams, Electronic, KC-135A Aircraft
1C-141A-1	C-141A Flight Manual
1C-141A-2-6	Technical Manual, Organizational Maintenance, Instruments, C-141A Aircraft
1C-141A-2-8	Technical Manual, Organizational Maintenance, Radio, Communications, and Navigation Systems
1C-141A-2-11	Technical Manual, Organizational Maintenance, Aircraft Wiring Diagrams for C-141A Aircraft
1H-53(H)B-1	HH-53 Flight Manual
1H-53(H)B-01	List of Applicable Publications, HH-53B, C Aircraft
1H-53(H)B-2-1	Organizational Maintenance Instructions, HH-53B, C Aircraft
1H-53(H)B-3	Structural Repair Instructions, HH-53B, C Aircraft
1H-53(H)B-4	Illustrated Parts Breakdown, HH-53B, C Aircraft
5F5-5-7-3	Technical Manual, Overhaul Instructions, Flight Director Computer Type CPU-65/A
5F8-5-10-3	Depot Maintenance Manual, Flight Director Indicator Part Number 353-999-0100
5F8-16-3-3	Technical Manual, Overhaul, Horizontal Situation Indicator Type AQU-2/A
5F8-16-4-3	Technical Manual, Overhaul, Horizontal Situation Indicator Type AQU-4/A
12P4-2APX-25-2	Field Maintenance Instructions, Transponder Set, Type AN/APX-25

12P4-2APX64-2	Field Maintenance Instructions, Radio Receiver – XMTR, Type RT-727/APX64(V), 728/APX-64(V), 731/APX-64(V), 727A/APX-64(V), 728A/APX-64(V) or 731A/APX-64(V), Part of Transponder Set AN/APX-64(V)
12P4-2APX65-2	Field Maintenance Instructions, Interrogator Set, Type AN/APX-65A
12P4-2APX72-2	Intermediate and Direct GS Maintenance with Depot O/H Instructions, Receiver XMTR, Radio RT-859/APX-72, 859A/APX-72, Mountings MT-3809/APX-72, MT-3948/APX-72
12P4-2APX76-2	Intermediate/Field and Depot Maintenance Instructions, Interrogator Set, Type AN/APX-76A(V) Electrical Equipment, Shock Mount Base MT-3924/APX-76(V), 3923/APX-76(V), 4024/APX-76A(V), Receiver-transmitter Type RT-901/APX-83(V)
12P5-2AFN59-22CL-1	Field Maintenance Instructions (Bench Check), Radar Set, Type AN/APN-59B
12R2-2ARC58-2	Field Maintenance Instructions, Radio Set, Type AN/ARC-58
12R2-2ARC65-2	Field Maintenance Instructions, Radio Set, Type AN/ARC-65A
12R2-2ARC90-2	Field Maintenance Instructions, Radio Set, Type AN/ARC-90
12R2-2ARQ23-2-1	Field Maintenance Instructions, AN/ARQ Equipment, GEN Communication Navigation Set, Type AN/ARQ-23
12R2-4-62-2	Type 618M-1C and 807A Service, Circuit Diagrams, Radio Receiver-XMTR
12R4-2ARN72-3	Technical Manual, Overhaul Instructions, Radio Set AN/ARN-72
12R5-1ARN52-12	Technical Manual, Organizational, Intermediate and Depot, TACAN Navigational Set AN/ARN-56(V)
12R5-1ARN72-2	Field Maintenance Instructions, Radio Set AN/ARN-72
12R5-1ARN-383	Technical Manual, Overhaul Instructions, Bearing-Distance-Heading Indicator Type ID-1103/ARN, Model DSB-357

12R5-1ARN-393	Technical Manual, Overhaul Instructions, Bearing-Distance-Heading Indicator Type ID-1103/ARN, Part Number 5201103001
12R5-2ARN21-1	Handbook, Operating Instructions, Radio Set AN/ARN-21
12R5-2ARN21-1C	Supplement, Technical Manual, Operating Instructions, Radio Set AN/ARN-21
12R5-2ARN21-2	Technical Manual, Handbook Service Instructions, Radio Set AN/ARN-21
12R5-2ARN21-3	Handbook, Overhaul Instructions, Radio Set AN/ARN-21
12R5-2ARN21-42	Technical Manual, Field Maintenance Instructions, Radio Set AN/ARN-21C
12R5-2ARN21-43	Technical Manual, Overhaul, Radio Set AN/ARN-21C
12R5-2ARN52-1	Handbook, Operational Instructions, TACAN Navigational Set AN/ARN-52
12R5-2ARN52-2	Technical Manual, Service Instructions, TACAN Navigational Set AN/ARN-52(V)
12R5-2ARN65-2	Technical Manual, Field Maintenance Instructions, Radio Set Type AN/ARN-65
12R5-2ARN-163	Technical Manual, Overhaul Instructions, Radio Magnetic Indicator Type ID-250/ARN
12R5-2ARN-193	Handbook, Overhaul Instructions, Course Indicator ID-249A & B, ID-34A & B, ID-387
12R5-2ARN-323	Technical Manual, Overhaul Bearing-Distance-Heading Indicator Type ID 1103/ARN, Part Number 101580
12R5-2ARN-333	Technical Manual, Overhaul Instructions, Bearing-Distance-Heading Indicator Type ID-1103/ARN Part Number 9813-06
12R5-2ARN-403	Technical Manual, Overhaul Instructions, Bearing-Distance-Heading Indicator Part Number 18-1686, Type ID-1103/ARN and ID-1103A/ARN
12R5-4-28-2	Handbook, Field Maintenance Instructions, TACAN Instrumentation Coupler 161B-1 and Shockmount 349L-2

12R5-4-28-3	Handbook, Overhaul Instructions, TACAN Instrumentation Coupler 161B-1 and Shockmount 349L-2
12R5-4-93-12	Technical Manual, Field Maintenance Instructions with Overhaul Maintenance, Horizontal Situation Indicator Type 331A-8H
12R5-4-123-2	Technical Manual, Maintenance Manual FD-109(V), Integrated Dual Flight Director/Rotation Go-Around Systems

A.3 NAVY TECHNICAL MANUALS

NAVAIR 01-75PAC-1	NATOPS Flight Manual, Navy Model P-3C Aircraft
NAVAIR 01-75PAC-1.2	NATOPS Crew Operators Manual (NAV/COMM), Navy Model P-3C Aircraft
NAVAIR 01-75PAC-2-9	Technical Manual, Maintenance Instructions, Organizational - Integrated Navigation System, P-3C Aircraft
NAVAIR 01-75PAC-2-9.1	Technical Manual, Maintenance Instructions, Organizational - Flight Director System and HSI Group, P-3C Aircraft
NAVAIR 01-75PAC-2-9.4	Technical Manual, Maintenance Instructions, Organizational - Radio Navigation System, P-3C Aircraft
NAVAIR 01-75PAC-2-9.7	Technical Manual, Maintenance Instructions, Organizational - Navigation Systems Wiring Data, P-3C Aircraft
NAVAIR 01-75PAA-2-11	Maintenance Instruction Manual, Autopilot and Instrument Groups, P-3C Aircraft
NAVAIR 01-75PAC-2-12	Technical Manual, Maintenance Instructions, Organizational, Instrument Systems, P-3C Aircraft
NAVAIR 01-75PAC-2-12.1	Technical Manual, Maintenance Instructions, Organizational, Automatic Pilot and Instrument Systems Wiring Diagram, P-3C Aircraft
NAVAIR 01-75PAC-2-12.2	Technical Manual, Maintenance Instructions, Organizational, Automatic Flight Control System, P-3C Aircraft
NAVAIR 01-75PAC-2-14	Technical Manual, Maintenance Instructions, Organizational, Airframe, Hydraulic and Utility Systems Wiring Data, P-3C Aircraft

NAVAIR 01-75PAC-4-8	Technical Manual, Illustrated Parts Breakdown - Communication and Navigation Electronic Systems, P-3C Aircraft
NAVAIR 05-40HA-5	Technical Manual, Overhaul Instructions - Horizontal Situation Indicators Type ID-1013/A, ID-1540/A
NAVAIR 05-40HA-6	Technical Manual, Illustrated Parts Breakdown - Horizontal Situation Indicators Type ID-1013/A, ID-1540/A
NAVAIR 16-35AM4923-1	Preliminary Technical Manual, Illustrated Parts Breakdown, - Depot Electronic Control Amplifier Central Repeater AM-4923/A

A.4 OTHER PUBLICATIONS

SS-US-101B 30 Sept 1974	System Segment Specification for the User System Segment of the NAVSTAR Global Positioning System, Phase I
P3631007	General Dynamics Proposal to SAMSO/JPO for the NAVSTAR Global Positioning System; Volume 2, User System Segment, June 1974
LR26378 Revision 1 16 Sept 1974	P-3 Avionic Equipment Specification Review Report, Lockheed-California Company
Lockheed-Georgia Report ER-6707 6 April 1966	HC-130 Noise and Vibration Test Report
Lockheed-Georgia Report ER-5047-II 15 Oct 1965	C-141A environmental report (title unknown)
AFML-TR-73-305 March 1974	Constrained Layer Treatments for Noise Control in a Helicopter
AFFDL-TR-73-160 Feb 1974	Vibration and Acoustic Environment of UH-1C Configured with and Using M-5 and XM-21 Armament
SER-65651 (Sikorsky) Part IV 15 Jan 1975	Vibration Ground and Flight Tests of the HH-53C Cantilevered Auxiliary Tank Support Installation
SES-650005 (Sikorsky) 17 Jan 1973	Detailed Specification for Model HH-53C Helicopter for the United States Air Force

523-0765298-00111W 10 Dec 1973	Collins AN/ARN-118(V) TACAN ASD Presentation
Spec No. 2102114 Revision A 11 Sept 1974	Prime Item Product Fabrication Specification for Navigation Set TACAN AN/ARN-119(V)
General Dynamics Electronics	Program Review, AN/ARN-119 TACAN
ARINC Specification 404A 15 March 1974	Air Transport Equipment Cases and Racking
ARINC Report No. 414 3 Sept 1968	General Guidance for Eouipment and Installation Designers
ARINC Characteristic 582-2	Mark 2 Air Transport Area Navigation System
–	U.S. National Standards for Common System Component Characteristics for the IFF Mark X (SIF)/Air Traffic Control Radar Beacon Systems SIF/ATCRBS
ASD, R&D Exhibit ENFI 72-11 19 Sept 1972*	Military Specification, Indicator, Horizontal Situation AQU-11/A

*Preliminary draft to military specification.

APPENDIX B
ORGANIZATIONS/INDIVIDUALS CONTACTED

B.1 U.S. AIR FORCE

OCALC

Lou Atkinson, KC-135 Technical Services, Avionics & Electrical
John Hamilton, KC-135 Technical Services, Avionics & Electrical
Lt. Col. Jacob Johnson, Chief, KC-135 Technical Services
Marland Noak, KC-135 Technical Services, Structures & Utilities
James Ray, KC-135 Technical Services, Structures & Utilities
Duard Rosenbaum, KC-135 Engineering
Billy Taylor, KC-135 Engineering
George Thompson, KC-135 Technical Services, Avionics & Electrical

WRALC

E. Clackler, MMATB HH-53 Technical Services
J. Collins, MMTTC Technical Services
Capt. M. Corcoran, MMAO HH-53 System Manager
K. Hines, MMHTA Technical Services
Lt. Col. J. Jamieson, MMHO C-141 System Manager
J. King, MMHT Technical Services
Lt. Col. R.M. Martin, MMHO C-130 System Manager
Maj. R.M. Morris, MMHO C-130 Program
Maj. A.D. Patchin, MMEW Aircraft Systems Engineering
A. Phelps, MMEW Aircraft Systems Engineering
Maj. B. Piper, MMAO HH-53 System Manager
L. Reese, MMHTB Technical Services
R. Roberts, MMTTC Technical Services
S. Smith, MMHO C-141 System Manager
J. Thompson, MMLO GPS Deputy Test Director, Logistics
R. Wheat, MMHT Technical Services (C-141 and C-130)
P. Wrigley, MMEW Aircraft Systems Engineering

March AFB

Lt. Col. D. January, 303rd Air Rescue Maintenance

Wright-Patterson AFB

Flight Dynamics Laboratory

Dr. A. Burkhard, Combined Stress Testing Lab

ASD Specialized Systems Program Office

J. Graves, PAVE Low III Project Staff

B.2 U.S. NAVY/MARINE CORPS

NARF San Diego

E.A. Anderson, Code 52103
E. Clary, Helicopter Rework
M. Morgan, Helicopter Rework

MCAS(H), Santa Ana, MAW-16

Capt. G.P. Kirchglssner, Headquarters Staff
Capt. W. Weaver

B.3 CIVILIAN/INDUSTRIAL

Analog Device Inc.

B. Cordwin

The Boeing Co.

T. Chadwick
D. Fitch
R. Kellerman
G. Markley
R. Robbins
R. Rouse
C. Schneider
C. Wittenborn

General Dynamics

H. Newman

ILC Data Device Corporation

Bill Wille, Regional Manager

Interface Engineering Inc.

Ralf Conner

ITT Cannon

D. Hadley

Lockheed-California Co.

R. Burch
R. Clanton
W. Fleeson
R. Norris
R. Reilly

Lockheed-California Co. (Cont)

J. Shea
C. Smith
G. Welter

Lockheed-Georgia Co.

E. Forsgren
J. Millard
B. Montgomery
F. Overcash
G. Smith

Lord Kinematics

G. Tillman

Magnavox

M. Bittner
V. Calbi
W. Chitty
P. Deem
G. Gunther
C. Haefner
D. Hessick
L. Jacobsen
R. Neff
R. Severence

Micio Network Corporation

Woody English

Natel Engineering Corporation

James Naster, Sales Manager

North Atlantic Industries

Bud Napoli
Bud Nelson

Sikorsky Aircraft

H. Nacklin, Sikorsky Representative, San Diego

Transmagnetics

George Comeau